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Lab to farm: mapping knowledge transfer channels and determinants from researchers' perspective – A systematic literature review

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ABSTRACT

The literature on the research–practice gap in agriculture has evolved significantly in recent decades. Although there is a well-established body of work on how farmers adopt agricultural research outcomes and the factors that influence their adoption, research on how researchers perceive the process of transferring their results to practical applications, along with the factors that facilitate or hinder this process, remains inadequate. This study addresses this gap by conducting a systematic literature review of empirical studies on knowledge transfer and its determinants from the perspective of agricultural researchers, covering publications from 1960 to 2024. It offers two key contributions: first, an original taxonomy of the channels through which agricultural research is transferred to farmers, and second, an integrative conceptual framework that links knowledge transfer to three categories of influential factors, related to researchers' individual characteristics, the organizational context within research institutions, and the external environment. Based on the findings, a research agenda has been developed to serve as a foundation for future investigations into persistent gaps in the field. The findings hold value for both academic and practitioner communities as they provide deeper insights to improve the understanding and practice of knowledge transfer in agriculture.

Introduction

The emergence of the knowledge society era in the 1990s (Lytovchenko et al., 2022) has caused a transition from agrarian and industrial societies to a knowledge-based society primarily stemming from the widespread availability and abundance of complex and massive data, as well as revolutionary advances in digital and information and communication technologies (ICTs) (Bilan et al., 2023). The agricultural sector has not been immune to these changes, with recent years witnessing a wave of modernization driven by the widespread adoption of next-generation digital technologies (NGDTs), such as artificial intelligence (AI), the internet of things (IoT), big data (BD), and nanotechnology (Purnama & Sejati, 2023). Rapid scientific and technological advances in the agricultural sector have given rise to a spectrum of terms to characterize these changes, variously labeled as "agriculture 4.0″, "digital agricultural revolution," "connected agriculture," "digital farming," and "AgTech" (Jakku et al., 2023; Martin & Schnebelin, 2023). With automated irrigation systems, GPS-guided tractors, aerial imagery, soil sensors for AI-driven crop monitoring, and nanotech-enhanced fertilizers, the possibilities for innovation in agriculture are unlimited (Danai-Varsou et al., 2023; Nemade et al., 2023). Consequently, farmers are becoming data-driven decision--makers (Rozenstein et al., 2024). The integration of advanced predictive analytics, fueled by comprehensive and high-quality data, empowers farmers with the capability to access up-to-date and relevant information on various aspects, such as weather forecasts, market dynamics, pricing of agricultural inputs (e.g., seeds, fertilizers, and pesticides), and advanced farming techniques (Farooqui et al., 2024; Karunathilake et al., 2023; Rozenstein et al., 2024). Overall, these advances empower farmers to make more informed decisions, effectively manage on-farm production, and proactively optimize farm efficiency.

Agricultural innovation begins in research laboratories and institutions, where innovative ideas and cutting-edge technologies are developed. Research and development (R&D) in agriculture remains a priority for diverse stakeholders, including government bodies, public or private research institutions, and higher education institutions (HEIs). (Anandajayasekeram, 2022; Yongabo & Göktepe-Hultén, 2021). In the context of research promotion, funders are focused on bolstering the scientific productivity of researchers and promoting research excellence among scholars and HEIs (Arnott et al., 2020). However, despite the

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involvement of numerous researchers in advancing knowledge, the agricultural research community often encounters difficulties in transferring its research results beyond the confines of the institution (Ansari et al., 2016; Hočevar & Istenič, 2014; Ifeanyi-obi & Asuquo, 2023; Theodorakopoulos et al., 2012; Yaakub et al., 2011). Practical applications of agricultural research remain suboptimal. Scientific research outcomes are often relegated to forgotten drawers and are underutilized or even disregarded altogether in agricultural practice (Koutsouris, 2012). Consequently, the transfer of evidence-based knowledge to actionable outcomes in agriculture remains a complex and multifaceted challenge (Chen & Li, 2022; McCown, 2001; Theodorakopoulos et al., 2012).

Researchers face challenges in integrating farmer-centric needs within research projects, whereas farmers perceive scientific research as distant or irrelevant to their agricultural practices (Bayissa, 2015a). The divergence of priorities between researchers, driven by a quest for theoretical knowledge and progress, and practitioners geared towards solving concrete, real-world problems, hinders the alignment of scientific results with field applications (Amara et al., 2019; Caplan, 1979), especially since the process of generating scientific knowledge is highly time-consuming and can span several years. Researchers spend time in comprehensive studies, whereas practitioners seek timely, pragmatic, and tangible solutions to address immediate issues (Amara et al., 2019; Cruz et al., 2022; Tucker & Lowe, 2014). Consequently, an ever-widening gap persists between the scientific and agricultural communities (Abereijo, 2015; Carayannis et al., 2018; Dutrénit et al., 2016; Higgins, 1991; McCown, 2001; Romańczyk et al., 2012). This research–practice gap restricts the effective transfer of innovative solutions from scientific knowledge to actionable practices (Bansal et al., 2012; Böckel et al., 2021; Carter, 2008; Neal et al., 2015; Tucker & Lowe, 2014; Tucker & Parker, 2014), begging the important question of how to bridge the research–practice gap in agriculture to enhance the effective transfer of scientific findings among farmers. Although research provides significant insights into how farmers adopt new agricultural practices and what factors influence their decisions, less is known about how researchers perceive the process of transferring their findings to practical applications in agriculture (Cruz et al., 2022). This study systematically reviews the state of knowledge transfer from researchers' perspectives, with a two-pronged aim: first, to develop a taxonomy of knowledge transfer channels between agricultural research and farmers, and second, to identify, from the researchers' perspective, the factors that either facilitate or hinder this transfer. To this end, this study explored three key research questions.

1. How has the research–practice gap been conceptualized in agricultural literature?
2. What formal and informal channels do agricultural researchers use to transfer knowledge to farmers?
3. What factors serve as facilitators or barriers to closing this gap?

To address these research questions, this study employs a rigorous and comprehensive systematic literature review (SLR), analyzing a corpus of articles spanning >60 years. Based on the findings of this extensive analysis, it proposes a research agenda that outlines key recommendations and promising future research avenues.

The remainder of this paper is organized as follows. Section 1 provides an in-depth overview of the methodological protocols used in this study, elaborating on the SLR method used to identify, select, analyze, and synthesize the relevant literature of the past 64 years. Section 2 presents the descriptive and analytical findings, based on which an integrative conceptual framework of knowledge transfer and its determinants within the agricultural sector are developed. Finally, Section 3 highlights the key contributions, outlines the research agenda for future studies, and addresses its limitations.

Method

Rationale for using the systematic literature review

This study adopted the SLR method to provide a state-of-the-art review of knowledge transfer in the agricultural sector. Unlike other types of reviews (e.g., narrative literature reviews and scoping literature reviews), the SLR is a rigorous, exhaustive, replicable, and transparent research method that involves a structured process of identifying, selecting, analyzing, and summarizing existing research on a specific topic (Denyer & Tranfield, 2009; Sauer & Seuring, 2023).

Such an approach is used for several reasons. Knowledge transfer is a multidisciplinary field often subject to a wide range of research conducted across different disciplines and scattered across diverse publications and journals. Many articles on this topic have been published in scientific journals that do not specialize in agriculture. Second, several studies have focused on the gap between agricultural researchers and farmers, their results are not linked to an integrative conceptual framework. Because current knowledge has been developed in silos, this does not allow for the development of a holistic view of state-of-the-art knowledge transfer from agricultural researchers to farmers. Third, research on knowledge transfer between agricultural researchers and practitioners in the agricultural milieu has experienced a surge of interest since the development of diffusion models for agricultural innovation in the early 1960s (Rogers, 1962). As a result, the extant literature on this topic has failed to provide a comprehensive understanding of the gap between these two communities of practice. An SLR might be an efficient method of organizing a state-of-the-art knowledge transfer from agricultural researchers to farmers, providing a comprehensive overview that cannot be obtained through a single or few studies and fostering potential avenues towards novel breakthroughs and advances in both theory and practice.

In 2016, a literature review (not an SLR) was conducted by Elueze on knowledge translation in agriculture, which primarily intended to examine the knowledge transfer process in agriculture following the Lavis knowledge transfer framework (Lavis, 2003). This framework is based on five cornerstones: the message, target audience, messenger, KT process and support system, and evaluation of the effect of the knowledge transferred. The findings of this study highlight that agricultural researchers are the main messengers of knowledge transfer to farmers, and that, notwithstanding a variety of potential users of agricultural knowledge, the most popular target audience for researchers is farmers. The author called for more studies focusing on knowledge transfer to policymakers for better evidence-based policy decisions, and a further explication of the role played by libraries and information science professionals in agriculture research knowledge transfer. However, Elueze (2016) did not, like the present study, aim to identify the knowledge transfer channels used by agricultural researchers to reach farmers nor build an integrative conceptual framework linking knowledge transfer from agricultural researchers to farmers to its determinants.

Research questions

This SLR aimed to provide a comprehensive synthesis of existing research that satisfies our inclusion and exclusion criteria, offering a detailed understanding of how the research–practice gap is perceived and addressed within the agricultural community. Specifically, the systematic literature review attempts to answer the following questions: 1) How has the gap between research and practice been conceptualized in the agricultural literature? (2) What are the formal and informal means of knowledge transfer used by agricultural researchers to reach farmers? 3) What are the levers and impediments, from the perspective of agricultural researchers, that may explain this gap?

Search strategy

The SLR was performed using the SALSA framework (Booth et al., 2013; Grant & Booth, 2009), which provides an explicit, transferable, and reproducible procedure for conducting it (García-Holgado et al., 2020; Mengist et al., 2020; Yeboah et al., 2023). It encompasses a four-stage process—search, appraisal, synthesis, and analysis (SALSA)—the first of which is the "search stage" that aims to gather a preliminary list of publications to analyze. It deals with search strategy and delivery, notably the definition and construction of the keyword chain and the choice of relevant databases to collect information. Second, the "appraisal stage" involves two basic steps: 1) identifying the relevant articles based on inclusion and exclusion criteria, and 2) assessing the quality of selected articles. Third, the "synthesis stage" consists of both extraction and classification of relevant data from selected papers. Finally, the "analysis stage" involved assessing the synthesized data, extracting significant information and drawing conclusions from the selected articles. Here, the SLR was analyzed against the SALSA framework described next.

Stage 1: search

Booth et al. (2013) advise that any literature search risks missing relevant items given the inclusion and exclusion criteria used to conduct the search. To address this problem, a search was conducted using the broadest possible terms related to the knowledge gap between agricultural researchers and farmers. An expert librarian corroborated the choice of the relevant databases. The search encompassed three multidisciplinary electronic databases –*Web of Science (Clarivate Analytics), ABI/Inform Global (ProQuest), Business Source Premier (EBSCO)* – and two specialized electronic databases – *CAB Abstracts (OVID), Eric (EBSCO)*. These databases were selected because they provide a large coverage of the relevant literature. The fact that the concept of the knowledge gap between research and practice has been the subject of contributions from various research fields (e.g., Chi, 2021 – education; Newnam et al., 2020 –medicine; Greene, 2021 – psychology; Ivanov et al., 2021 – management) justifies the use of multidisciplinary databases. The databases were accessed from the websites of the authors' university libraries. The expert librarian also participated in building a keyword chain. The list of keywords was obtained by snowballing, which included bibliographic referencing, back-referencing (reviewing the references of included studies), and citation tracking (Petticrew & Roberts, 2006). The keyword chain combined three key concepts. The first key concept referred to the theme of knowledge transfer, the second included keywords related to academic and scientific fields, and the third included keywords related to agriculture. These concepts and their synonyms were used in various combinations with Boolean operators "AND" (to obtain results that include all search terms simultaneously) and "OR" (to include alternative terms or synonyms). The following keywords were used to identify relevant articles.

Transfer* OR "knowledge transfer" OR diffus* OR "knowledge diffusion" OR disseminat* OR "knowledge dissemination" OR translat* OR "knowledge translation" OR uptake* OR "knowledge uptake" OR exchange OR "knowledge exchange" OR shar* OR "knowledge sharing" OR "knowledge circulation" OR "knowledge spread" OR "know-how transfer" OR "knowledge transmission" OR gap OR "knowledge gap" OR "research–practice" OR "research–practice gap" OR implement* OR "knowledge implementation" OR knowledge application* AND Research* OR professor* OR scien* OR academic* OR "agricultural researcher" OR scholar* OR "agricultural researchers" OR "scientific community" OR "scientific communities" OR faculty member* OR facult* OR "research institutes" OR universit* OR higher education institution* OR HEI* OR research center* AND agricult* OR farm* OR farm worker* OR agricultural worker* OR rural sector OR rural* OR agricultural laborer* OR rural farm resident* OR agricultural business OR agricultural communit* OR agricultural producer* OR agricultural agencie*

All articles from each database were indexed using *Endnote* software. Then, an examination of all identified articles was carried out. After eliminating 732 duplicate studies, 5837 potentially unique eligible articles for this systematic literature review were obtained (Table 1).

Stage 2: appraisal

This stage mainly involved the application of the exclusion and inclusion criteria established with respect to the research questions. These criteria, along with a description of the study rationale, are presented in Table 2.

Each article was sequentially evaluated based on these criteria and was excluded if any criterion was not met. The sifting process had four stages. All titles, keywords, and abstracts were reviewed to eliminate publications that did not focus on the transfer of agricultural knowledge from researchers to farmers. This first screening procedure enabled the exclusion of 4731 articles that did not meet all the criteria. Subsequently, a second, deeper shifting based on a reading of the methodology and results of the study was performed on the 1106 articles remaining from the first screening. This sorting eliminated 1034 articles. The remaining 72 articles were examined in detail. A detailed analysis of the full texts allowed the elimination of 45 papers; thus, 27 articles remained. Finally, one-step backward snowballing (Jalali & Wohlin, 2012) was performed on the remaining 27 papers. To achieve this, a systematic hand search was conducted on the reference lists of the final set of selected articles to identify additional relevant articles that had not been uncovered through previous search strategies. This search allowed for the incorporation of three supplementary publications (Paunović et al., 2022; Rathod et al., 2018). Finally, the set of analyzed papers that matched all the inclusion criteria amounted to 30 articles published in 26 different peer-reviewed journals. This number is comparable to the number of selected articles in several other literature reviews in different research fields (e.g., Elueze (2016): Translation in agriculture (27 articles); Ratajczak & Szutowski (2016): CSR and innovation (24 articles); Cloutier & Amara (2023): Innovation cooperation for manufacturing SMEs (29 articles)). The flow diagram in Fig. 1 summarizes the successive electronic and manual iterations, leading to the final selected set of articles for analysis.

Stages 3 and 4: synthesis and analysis

All 30 selected articles were managed using computer-based methods following the approach outlined by Petticrew (2006). For this study, a Microsoft Excel database was developed to effectively summarize key information from each article. This database included the details, such as the article's reference, explicit definitions of knowledge transfer and its determinants, channels used by researchers to disseminate their research findings, unit of analysis considered, methodological approach utilized, analytical techniques applied, geographical context of the study, and other relevant data. The database served as a valuable

Table 1
Results of electronic databases search.

DATABASE	SCIENTIFIC ARTICLES IDENTIFIED	DUPLICATES	UNIQUE ITEMS
MULTIDISCIPLINARY DATABASES			
Web of science (Clarivate Analytics)	**1437**	**289**	**1148**
ABI/INFORM global (ProQuest)	**1523**	**91**	**1432**
Business Source Premier (EBSCO)	**991**	**42**	**949**
SPECIALIZED DATABASES			
CAB (OVID)	**2150**	**268**	**1882**
Eric (EBSCO)	**468**	**42**	**426**
TOTAL	**6569**	**732**	**5837**

Table 2
Exclusion and inclusion criteria.

CRITERIA TYPE	CRITERIA	RATIONALE
INCLUSION CRITERIA		
Type of document	The selected documents consist of scientific papers published in peer-reviewed journals, emphasizing the importance of ensuring the reliability of the findings.	The articles are published in a scientific peer-reviewed journal, which notably excludes books (and book chapters), essays, master theses, doctoral theses, research notes, dissertations, and conference proceedings, etc. Additionally, for inclusion in the review, the full-text version of the articles had to be accessible to ensure no broken links or limitations to accessing the complete content.
Focus area	The primary focus of the selected articles is on the knowledge transfer within the agricultural field.	The articles that specifically discuss the concept of knowledge transfer or the gap between research and practice in the agricultural context were chosen. Additionally, the selected articles had to offer substantial information to facilitate a comprehensive review of the factors influencing knowledge transfer in agriculture. They were to specifically target the research perspective when examining the influential factors of knowledge transfer from agricultural researchers to agricultural community.
Unit of analysis	The unit of analysis for this study encompasses individual researchers, universities, research institutions, and other organizations involved in producing scientific research within the agricultural field.	The unit of analysis for this study was selected strategically. This decision was guided by our specific focus on identifying the barriers and facilitators that operate upstream in the knowledge transfer process, particularly at the level of knowledge producers (researchers).
Language	The selected articles are published in English.	Only articles written in the English language were considered for inclusion in the SLR. This decision was taken because a significant proportion of influential scientific publications in scholarly journals are published in English. By limiting the review to English-language articles, the study aimed to encompass a substantial body of relevant and impactful research in the field of agricultural knowledge transfer (Duszak & Lewkowicz, 2008; Henshall, 2018).
Temporality	The selected papers were published between January 1960 and June 2024 inclusively.	The rationale behind selecting 1960 as the reference point for our search is to trace the development of literature on knowledge and innovation diffusion within the agricultural domain, starting from the seminal work of Rogers (1962). The choice of 2024 as the concluding year was because it was the most recent year. Consequently, this time frame was expected to encompass the great majority of publications related to the subject matter under review.
Method	All types of empirical papers, including quantitative, qualitative, and mixed-methods studies, were included.	By focusing on empirical studies, this SLR aimed to identify the determinants of knowledge transfer considered across various contexts and settings and highlight the most recurrent predictors of knowledge transfer in agriculture.
EXCLUSION CRITERIA		
Type of document	All published studies other than articles published in scientific journals, are excluded from the SLR, namely books (books and book chapters), essays, research notes, conference proceedings, letters, short stories, dissertations, doctoral theses, grey literature, including non-peer-reviewed articles, etc. Articles not available in full text were also excluded.	The exclusion of these types of documents was carried out based on the consensus among several authors that important scientific contributions are primarily published in international peer-reviewed journals, which tend to have high impact on the field (Elsbach & Van Knippenberg, 2020; Post et al., 2020). Therefore, to uphold the quality of the study, only peer-reviewed articles from scholarly journals were included in the review.
Focus area	Articles that do not primarily address knowledge transfer within the agricultural field were excluded	
Unit of analysis	Articles that address units of analysis not directly involved in the production of scientific research within the agricultural field (such as farmers, producer unions, etc.) were excluded.	
Language	Articles published in languages other than English were excluded.	
Temporality	Papers published outside the specified timeframe (before January 1960 and after June 2024) were excluded.	
Method	Non-empirical studies (all other methods (e.g., theoretical/ conceptual)) were excluded.	

tool for organizing and synthesizing the collected information, enabling a comprehensive analysis of the findings from the selected articles.

The results of the synthesis and analysis of the research material corresponding to the last two steps of the SALSA method, are described in detail in the Results section. First, the general features of the included studies are presented. Subsequently, the analytical findings from the selected studies are discussed, enabling 1) edifying an integrative conceptual framework linking agricultural knowledge transfer with its levers and barriers, and 2) proposing a research agenda that highlights the most promising opportunities for future research.

Results

General characteristics of the selected studies

Distribution of the articles by publication outlet

Table 3 shows the distribution of the 30 articles selected from the 26 journals. The *Journal of Agricultural Education & Extension, Journal of Agricultural & Food Information* and the *American Journal of Human Ecology* each have two articles. All the other journals have only one article each. The third of the articles (10 out of 30 articles) were published in journals belonging to the first and second quartiles (Q1 and Q2), according to the journal impact factor ranking of the Web of Science Journal of Citation Report (e.g., *Technovation; Biological Conservation; Ecological Economics; Technological Forecasting & Social Change; Journal of Agricultural Education & Extension*). The list of journals identified from the SLR reveals a diverse array of publications covering several fields relevant to our research. This broad disciplinary spectrum results in a fragmented research landscape as studies span multiple domains, leading to a more dispersed body of work.

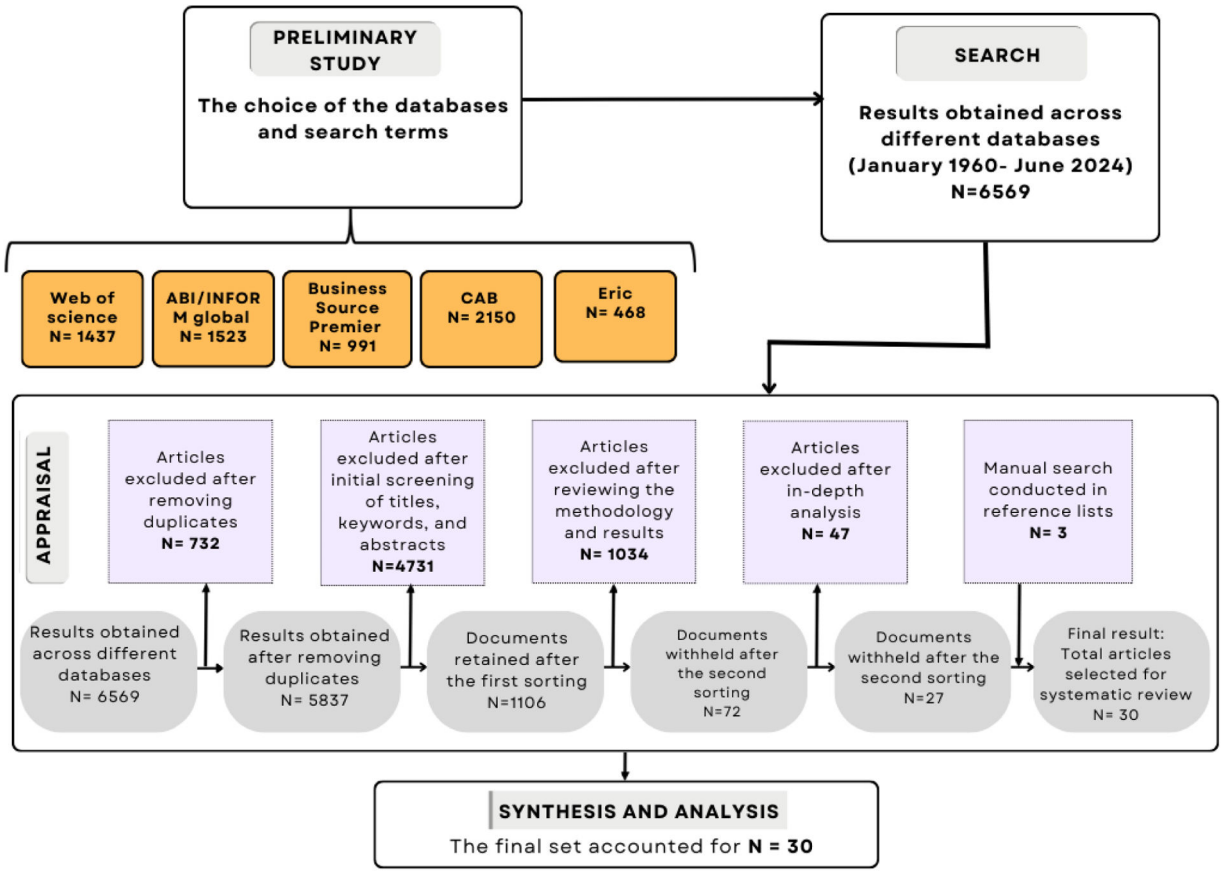

Fig. 1. The systematic literature review flow diagram.

Publication trend and countries studied

Overall, the trend shows a growing interest in transferring agricultural research to farmers over the past few decades, with a notable increase in recent years (Fig. 2). The findings showed that the number of publications related to the transfer of agricultural research to farmers increased significantly between 2013 and 2024. In 2013, there was a slight increase with three publications, followed by a significant increase in 2015, with five publications. Between 2016 and 2018, the number of publications stabilized slightly, with two publications each year, suggesting sustained interest but at a moderate pace. Between 2016 and 2021, publications continued at a steady pace, with two publications each year from 2016 to 2018, and one publication each year from 2019 to 2021. There was a marked increase between 2022 and 2023, with four publications in 2022 and two in 2023. Publications were sporadic from 1995 to 2012, with only one publication each in six years of this period, indicating perhaps a reduction in priority for the topic of transferring agricultural research to farmers. However, most of the articles (24 of 30) were published in the last decade, suggesting a clear gain in prominence for the topic in agricultural science research, particularly after 2012.

The distribution of articles by contry reflects the country being studied in the article rather than the author(s)' country of origin. This distribution shows that almost all (28) used data collected from only one country. The only two exceptions are Maas et al. (2021), which focused on Germany and Austria, and David et al. (2010), which examined India and Ethiopia. The most studied country is Nigeria, with 5 of the 30 articles, representing 16.67 % of the total (Faborodee & Ajayi, 2015; Ifeanyi-obi & Asuquo, 2023; Ifeanyieze et al., 2017; Mgbenka et al., 2013; Okocha, 1995). Ethiopia and Iran followed with four (13.33 %) articles each (Ethiopia – Ayalew & Abebe, 2018; Bayissa, 2015a, 2015b, 2015c; Iran – Ahmadinejad, 2020; Ansari et al., 2016; Karamidehkordi, 2013; Taheri et al., 2022). The United States follows with three, accounting for 10 % of the total (Duram & Larson, 2001; Getson et al., 2022; Larson & Duram, 2000). Twelve countries, Spain, South Africa, Colombia, India, Russia, Australia, Bulgaria, Indonesia, Mozambique, Slovenia, Slovakia, and Sri Lanka, were represented by one article each.

When considering the distribution of selected studies in major world regions, Africa had the highest proportion (37 %). Asia followed with 23 %, Europe 16.67 %, North America (USA) 10 %, South America 3.33 %, and other continents, 3.33 %. Studies involving multiple continents accounted for 6.67 % of the total (see Fig. A.1 in Appendix A).

Publication trends by unit of analysis and fields studied

The distribution of articles according to the unit of analysis shows a focus on multi-unit studies, encompassing agricultural researchers and other stakeholders (refer to Fig. A.2 in Appendix A). These studies represent 46 %, or 14 of 30 articles (e.g., Ansari et al., 2016; Karamidehkordi, 2013; Simbe, 2022; Taheri et al., 2022; Wheeler, 2008). Following closely are studies focusing specifically on agricultural researchers, with 40 %, or 12 of 30 articles (e.g., Ifeanyi-obi & Asuquo, 2023; Larson & Duram, 2000; Maas et al., 2021). Universities, research centers, and research institutes each account for 7 %, or 2 of 30 articles each (e.g., Dirimanova & Radev, 2017; Theodorakopoulos et al., 2012; Thurner & Zaichenko, 2018).

The distribution of articles in the field of application indicates that general agriculture is by far the most studied field, accounting for 67 % of the articles (20 of 30) (e.g., Ahmadinejad, 2020; Ansari et al., 2016; Okocha, 1995). This was followed by sustainable agriculture, representing 13 % (4) (e.g., Larson & Duram, 2000; Maas et al., 2021). Less frequently covered fields include agricultural innovation and the combination of fish farming and coffee production, each accounting for 7 %, or two articles (e.g., Theodorakopoulos et al., 2012), and rural and organic agriculture, represented by one each (e.g., Wheeler, 2008) (refer

Table 3
Distribution of the retained articles according to the journals (editorial trend).

NAME OF THE JOURNAL	NUMBER OF ARTICLES	CATEGORY
1. JOURNAL OF AGRICULTURAL EDUCATION & EXTENSION	2	• Education & Educational research
2. JOURNAL OF AGRICULTURAL & FOOD INFORMATION	2	• Agronomy
3. AMERICAN JOURNAL OF HUMAN ECOLOGY	2	• Human ecology
4. AFRICAN JOURNAL OF AGRICULTURAL RESEARCH	2	• Agriculture
5. AFRICA EDUCATION REVIEW	1	• Education & Educational research
6. BIOLOGICAL CONSERVATION	1	• Environmental sciences
7. ECOLOGICAL ECONOMICS	1	• Ecology
8. INTERNATIONAL JOURNAL OF TECHNOLOGY	1	• Engineering, multidisciplinary
9. JOURNAL OF AGRICULTURAL EXTENSION	1	• Agriculture
10. JOURNAL OF NATURAL RESOURCES AND ENVIRONMENTAL MANAGEMENT	1	• Environmental management
11. AMERICAN JOURNAL OF INTEGRATIVE AGRICULTURE	1	• Agriculture, multidisciplinary
12. PLOS ONE	1	• Multidisciplinary sciences
13. PROFESSIONAL GEOGRAPHER	1	• Geography
14. SCIENCE AND PUBLIC POLICY	1	• Environmental studies • Management
15. TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	1	• Regional & Urban planning
16. TECHNOVATION	1	• Engineering industrial
17. AMERICAN JOURNAL OF BUSINESS AND MANAGEMENT	1	• Business & Management
18. BULGARIAN JOURNAL OF AGRICULTURAL SCIENCE	1	• Environmental science
19. SCIENTIFIC JOURNAL OF APPLIED SOCIAL AND CLINICAL SCIENCE	1	• Social sciences
20. ANTHROPOLOGICAL NOTEBOOKS	1	• Anthropology
21. INTERNATIONAL JOURNAL OF AGRICULTURAL MANAGEMENT AND DEVELOPMENT	1	• Agriculture
22. INDIAN JOURNAL OF EXTENSION EDUCATION	1	• Education & Training
23. INTERNATIONAL JOURNAL OF ADVANCED RESEARCH	1	• Multidisciplinary
24. TROPICAL AGRICULTURAL RESEARCH	1	• Agriculture
25. THE INTERNATIONAL INFORMATION & LIBRARY REVIEW	1	• Library science
26. QUALITY INNOVATION PROSPERITY	1	• Management

to Fig. A.3 in Appendix A).

Distribution of articles by methodological approach and data collection technique

The most used methodology is quantitative, appearing in 47 % of the articles (14) (e.g., Cruz et al., 2022; Getson et al., 2022). This is followed by qualitative methodology, used in 13 articles, or 43 % (e.g., Ansari et al., 2016; Fongwa & Marais, 2016; Hočevar & Istenič, 2014; Karamidehkordi, 2013). This distribution reveals a nearly split between the quantitative and qualitative methodologies, indicating that both types of analysis were valued almost equally. Mixed methods, which combine both quantitative and qualitative approaches, were used in the remaining three (10 %) (e.g., Ifeanyi-obi & Asuquo, 2023) (refer to Fig. A.4 in Appendix A).

Table 4 details the various analytical techniques utilized in the selected articles. Content analysis is the most prevalent, featuring in 30 % of the articles (e.g., Ansari et al., 2016; Fongwa & Marais, 2016; Hočevar & Istenič, 2014). Multivariate regression techniques account for 16.7 % of the articles, with specific techniques under this category including structural equation modeling (Ahmadinejad, 2020; Taheri et al., 2022), logistic regression (Thurner & Zaichenko, 2018), and ordered probit regression (Wheeler, 2008). Multi-quantitative methods (e.g., Duram & Larson, 2001; Maas et al., 2021) and inferential statistics (e.g., Kaur & Kaur, 2013; Mgbenka et al., 2013) each were used in 13.3 % of the articles. Qualitative-quantitative methods appear in 10 % of the articles (e.g., Okocha, 1995). Case studies (e.g., Karamidehkordi, 2013), action research (e.g., Theodorakopoulos et al., 2012), multi-qualitative methods (e.g., Dharmawan et al., 2023), and Principal Component Analysis (PCA) (Cruz et al., 2022) were less commonly used.

Table 5 presents the distribution of articles based on data collection methods. Fourteen articles (46.67 %) used surveys (e.g., Ayalew & Abebe, 2018; Maas et al., 2021; Taheri et al., 2022; Wijerathna et al., 2015), followed by multiple data collection methods (6 or 20 %,) (e.g., Ifeanyi-Obi & Asuquo, 2023; Karamidehkordi, 2013). Interviews (e.g., Ansari et al., 2016; Bayissa, 2015a; Dharmawan et al., 2023) were used in eight (26.67 %), whereas documentation methods (e.g., Jarábková, 2019) and workshops and training (e.g., Theodorakopoulos et al., 2012) were the least common, each accounting for 3.33 % (one article).

Analytical findings

Putting the knowledge transfer in agriculture under the microscope: current definitions

Through the synthesis of 30 articles in the SLR, various definitions associated with the concept of knowledge transfer in the agricultural field were discerned (Table 6), which can be approached from three perspectives. 1) Definitions that perceive knowledge transfer as a sequential process: this perspective views knowledge transfer as a process that enables knowledge production by scientific researchers and its subsequent application in the agricultural sector and is closely aligned with the knowledge-driven model, also known as the "science push model" (Dilling & Lemos, 2011; Landry et al., 2001; Weiss, 1979). These definitions underscore the importance of ensuring that research outcomes reach farmers and agricultural practitioners. 2) Definitions that highlight the interactive aspects of the knowledge transfer process: from this perspective, knowledge transfer is an interactive process involving multiple stakeholders, including researchers, farmers, extension workers, policymakers, and other relevant actors within the agricultural ecosystem. It aligns with the "interactive model," which recognizes the non-linear, collaborative and dynamic nature of knowledge transfer process (Landry et al., 2001). 3) Definitions that consider knowledge transfer as a problem-solving mechanism for practical solutions and real-world benefits: this perspective considers knowledge transfer as a mechanism for addressing specific challenges in the agricultural sector and ensuring that scientific advancements translate into tangible socioeconomic benefits. This aligns with the "problem-solving model," also known as the "demand-pull model" (Landry et al., 2001; Weiss, 1979; Yin & Moore, 1988). The transfer of agricultural research is guided by the identification and prioritization of problem-oriented research that directly responds to the needs and problems faced by the agricultural community.

Theoretical anchorage of the selected studies

The SLR revealed that a majority of the articles (20, or 66.66 %) did not explicitly draw upon theoretical foundations to study knowledge transfer in the agricultural sector. The lack of a unified framework has likely led to a fragmented approach to the study of knowledge transfer, resulting in a plethora of perspectives that struggle to provide a comprehensive understanding of the process within the agricultural context. Table 7 provides a comprehensive overview of the distinct

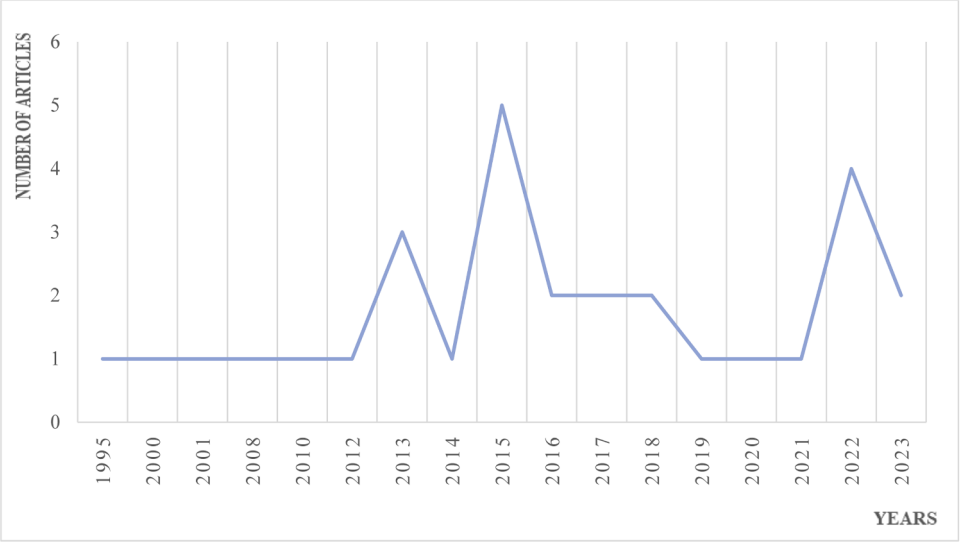

Fig. 2. Distribution of the number of articles per year (publication trend).

Table 4
Distribution of analytical techniques in the selected articles.

ANALYSIS TECHNIQUE	NUMBER OF ARTICLES	PROPORTION OF ARTICLES
Content analysis	9	30 %
Multivariate regression	4	16.7 %
• ***Structural Equation Modeling (SEM)***	2	50 %
• ***Logistic regression***	1	25 %
• ***Ordered probit regression***	1	25 %
Multi-quantitative methods	5	13.3 %
Qualitative-quantitative methods	3	10 %
Inferential statistics	4	13.3 %
Case studies	2	6.7 %
Research action	1	3.3 %
Multi-qualitative methods	1	3.3 %
Principal Component Analysis (PCA)	1	3.3 %
Total	**30**	**100 %**

Table 5
Distribution of articles by data collection technique.

DATA COLLECTION METHODS	NUMBER OF ARTICLES	PROPORTION OF ARTICLES
Survey	14	46.67 %
Interview	8	26.67 %
Documentation	1	3.33 %
Workshop and training	1	3.33 %
Multi-data collection methods	6	20 %
• **Focus group and survey and interviews**	1	25 %
• **Documentation and interviews**	1	25 %
• **Survey and interviews**	2	50 %
Total	**30**	**100**

theoretical perspectives identified in this SLR and corresponding articles. These theories include the diffusion of innovation (DOI) theory, information behavior theory, technology acceptance model (TAM), theory of planned behavior (TPB), situated learning or communities of practice (CoPs) theory, the adoption-diffusion model of innovation, Nonaka's knowledge creation theory, and the model of public engagement.

From the overview of the main theories utilized, one notices that some important theories in knowledge transfer and uptake literature have not been considered. To address this gap, three additional theoretical frameworks are suggested: resource-based view theory (RBV), neoinstitutional theory, and motivation theory. These theoretical frameworks, widely used to address knowledge transfer in other research fields (health, business, social sciences, engineering, etc.), are particularly relevant for addressing the persistent gap between the scientific research and agricultural communities. Table 8 highlights the theoretical foundations, main contributions, and analytical levels of these three theories.

Towards a taxonomy of knowledge transfer channels from agricultural researchers to farmers

The SLR of the 30 selected articles identified 19 different channels of knowledge transfer utilized by agricultural researchers to reach farmers. However, no conceptual categorization of these channels has been done. Following Jbilou (2010), the channels of knowledge transfer identified in this SLR are classified into two dimensions: the type of medium of the transfer and the form of the transfer. The former can be interactive oral, text-based, electronic, or structural media. The latter could be didactic (Estabrooks et al., 2008; Madsen, 2009), dialogic (Beech et al., 2010; Jones, 2000; Schmidt & Stadermann, 2023), tactical (Blumenthal & Thier, 2003; Liew et al., 2012; Newton et al., 2007), practical (Oermann et al., 2008), thematic (Estabrooks et al., 2008), electronic (Mairs et al., 2013), or strategic (Liew et al., 2012; Perkmann & Walsh, 2008). As advocated by Jbilou (2010, p. 94), the didactic form involves an interactive oral medium based on the demonstration of how to effectively use research findings, as well as a discussion with users of the implications of using these findings. The research results are thus presented in the context of teaching thanks to practical training courses, workshops, seminars, and conferences targeting practitioners. Similarly, the dialogic form also involves an interactive oral medium based on discussion and mutual exchange of the practical implications of the research findings and the conditions of their implementation. "During this exchange, both the researcher and the user are experts. One is an expert on the research result and its use, the other is an expert on the implementation environment and its contingencies" (Jbilou, 2010, p. 95, translated by authors). This form of transfer channel includes discussion groups, partnership platforms, exchange visits, and joint-on field research.

Knowledge transfer channels can also use written media in three different forms: tactical, practical, and thematic. These forms can be considered as strategies designed to achieve a specific objective: the use of research results. Specifically, the tactical form is based on the drafting

Table 6
Conceptual definitions of knowledge transfer within the selected studies.

CONCEPTUAL DEFINITION OF KNOWLEDGE TRANSFER IN AGRICULTURE	AUTHORS FROM SELECTED ARTICLES	PURPOSE
DEFINITIONS THAT PERCEIVE KNOWLEDGE TRANSFER AS A SEQUENTIAL PROCESS		
Research uptake activities involve all activities aimed at communicating research findings to the target audience to ensure that the target audience utilizes the research outcomes.	Ifeanyi-obi and Asuquo (2023, p. 16).	Definitions that perceive knowledge transfer as a process enabling the production of knowledge by scientific researchers and its application within the agriculture.
Technology transfer is the main component of technology development. This is because, for the developed technology to be applied effectively, it needs to reach the end users of the technology with its full package. The feedback needs to reach the developer of the technology as well to involve all actors in the decision-making.	Ayalew & Abebe (2018, p. 683).	
Technology transfer is a critical process in transforming agricultural research innovations into applications for end users. It helps to improve economic growth, transform lives and boost outputs.	Ifeanyieze et al. (2017, p. 2064).	
Research uptake includes all actions that aid and contribute to the use of research evidence by policymakers, practitioners and other development actors. It is aimed at stimulating end users of agricultural research findings, including policymakers, agricultural practitioners, researchers, and/or implementers, into growing aware of and accessing and applying research knowledge/ findings/output in agricultural policy and practice.	Ifeanyi-obi & Asuquo (2023, p. 16).	
Commercialization of knowledge is a process that transforms the knowledge generated into marketable products (Yadollahi Farsi and Kalathaie, 2012). It begins when a business is created as a way to use modern scientific and technological advancements, with the aim of responding to market demands through design, development, manufacturing, marketing, and subsequent efforts to improve the product (Mehta, 2008).	Ahmadinejad (2020, p. 150).	
Davenport and Prusak (1998) argue that knowledge transfer involves two actions, namely, transmission (the process of sending knowledge to a potential recipient) and absorption (by the recipient – person/ institution).	Fongwa & Marais (2016, p. 193).	
Technology transfer includes direct or indirect transmission of scientific knowledge to real life (Brennenraedts, Bekkers and Verspagen, 2006).	Jarábková et al. (2019, p. 138).	
Technology transfer refers to deliberate, goal-oriented relationship between two or more persons, groups, or organizations who exchange technological knowledge (Autio and Laamanen, 1995).	Ifeanyieze et al. (2017, p. 2064).	
Technology transfer refers to movement of ideas, inventions and prototypes within companies, from research producers to a wide group of users including government departments, non-profits, industries and universities (Harman and Harman, 2004).	Ifeanyieze et al. (2017, p. 2064).	
Stock and Tatikonda (2000) described technology transfer as the act of conveying and utilizing technological innovation by the recipient to achieve set objectives, within cost and time targets. Technology transfer is, therefore, the movement of relevant specialized knowledge or innovations from research institutes to farmers for adoption with the help of extension agents and providing feedback to researchers to achieve the intended objectives.	Ifeanyieze et al. (2017, p. 2064).	
DEFINITIONS THAT HIGHLIGHT THE INTERACTIVE ASPECT OF THE KNOWLEDGE TRANSFER PROCESS		
REFILS (Research-Extension-Farmer-Input Linkage System) provides a means of sharing information at the point of overlapping between its different actors through the use of various activities.	Faborode & Ajay (2015, p. 82).	Definitions that highlight the interactive aspect of knowledge transfer.
For effective transfer of technology, strong inter-organizational linkage is vital because of the involvement of various organizations in the process (Sen, 1984).	Kaur & Kaur (2013, p. 699).	
Technology transfer requires research stations to disseminate information through extension agents and others to ensure that target audience receive the innovation through media and other means.	Ifeanyieze et al. (2017, p. 2064).	
The rate at which technology transfer is accepted for	Ifeanyieze et al. (2017, p. 2064).	

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Table 6 (*continued*)

CONCEPTUAL DEFINITION OF KNOWLEDGE TRANSFER IN AGRICULTURE	AUTHORS FROM SELECTED ARTICLES	PURPOSE
adoption depends on the effectiveness of the linkages.		
DEFINITIONS THAT CONSIDER KNOWLEDGE TRANSFER AS A PROBLEM-SOLVING MECHANISM FOR PRACTICAL SOLUTIONS AND REAL-WORLD BENEFITS		
Technology transfer holds a great potential for promoting innovation and competitiveness at regional and national levels (Bennett and Vaidya, 2005).	Theodorakopoulos et al. (2012, p. 1).	Definitions that consider knowledge transfer as a corrective action.
Effective dissemination of information on sustainable agriculture is one way to encourage widespread adoption of sustainable farming systems.	Larson & Duram (2000, p. 173).	
The outreach, or extension, tasks refer to the more direct contribution of higher education in agriculture to agricultural and rural development. It may include educational programs for communities beyond the university campus, conducting policy, industry and community-oriented research on issues identified by the consumers, and offering various kinds of services to the community such as technical assistance and agricultural and rural planning (Van den Bor et al., 1989).	Wijerathna et al. (2015, p. 286).	

of illustrated and appealing reports for potential users, whereas the practical form designates a channel of knowledge transfer based on the publication of articles in professional journals, enabling research results to be presented in a practical way that is accessible to practitioners. The thematic form refers to a knowledge transfer channel that draws on the writing of reports on specific themes relevant to target audiences (Jbilou, 2010, p. 95). Knowledge transfer channels can also take forms based on electronic media, such as websites, blogs, online newspapers, and e-newsletters, described in electronic form. Finally, knowledge transfer channels can operate through a structural medium based on a formal contract that may have specific objectives, such as patenting innovations and creating spin-offs, and considered a strategic form of knowledge transfer.

The results of classifying the 19 channels of knowledge transfer identified in this SLR by type of transfer medium and form of transfer are presented in Table 9, which also indicates the formal or informal nature of each channel of transfer. To our knowledge, this original classification is the first taxonomy of channels of knowledge transfer from agricultural research to farmers.

Key determinants influencing knowledge transfer in agriculture: a researcher-centric view

A key objective of this study is to gain a better understanding of the determinants of knowledge transfer from agricultural researchers to the agricultural community. These determinants were systematically classified into three principal categories: 1) determinants related to the individual characteristics of agricultural researchers, 2) those related to the organizational context prevailing in universities and research centers, and 3) those related to the external environment.

Table 7
Principal theoretical frameworks adopted in knowledge transfer studies involving agriculture.

Theoretical perspectives	Foundational authors of these theoretical perspectives	Conceptual overview	Examples of articles of the SLR that discussed these theoretical perspectives
Diffusion of innovations theory/ Adoption-diffusion model of innovation	Rogers (1962)	The diffusion of innovation (DOI) theory, developed by Rogers (1962), explores the process by which innovations, technologies and ideas spread within a community. He also identified five categories of adopters (based on their willingness and speed to adopt innovations): innovators, early adopters, early majority, late majority, and laggards. Additionally, the DOI theory highlights five key attributes of innovations that influence the rate of adoption: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003).	Larson & Duram (2000) Duram & Larson (2001)
Information behavior theories: •Cost-Benefit Model. •Least-Effort Model.	Hardy (1982) Zipf (1949)	The cost-benefit model and the least-effort model, proposed by Hardy in 1982 and drawing on Zipf`s Law of Least Effort from 1949, are two influential theories in information-seeking behavior that help to explain how individuals choose information sources. The first model suggests that individuals evaluate the expected benefits of obtaining information against the potential cost. Information-seekers are more likely to choose sources that offer the greatest benefits, even if accessing these sources requires more effort. The second suggests that individuals tend to minimize the effort needed to	Okocha (1995)

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Table 7 (*continued*)

Theoretical perspectives	Foundational authors of these theoretical perspectives	Conceptual overview	Examples of articles of the SLR that discussed these theoretical perspectives
		obtain information, even at the expense of information quality, presenting a different approach to understanding information-seeking behavior.	
Technology acceptance model (TAM)	Davis (1989)	The TAM, proposed by Davis in 1989, offers a framework for understanding user acceptance and utilization of technology. It suggests that the intention to use a technology is primarily influenced by perceived usefulness, and perceived ease of use.	Taheri et al. (2022)
Theory of planned behavior (TPB)	Ajzen (1988) Ajzen (1991) Ajzen (2011)	The TPB, developed by Ajzen in the late 1980s, is a psychological framework that seeks to explain human behavior through three core components: attitudes, social aspect (or subjective norms), and perceived behavioral control.	Wijerathna et al. (2015)
Situated learning or communities of practice (CoPs) theory	Lave & Wenger (1991) Lave (1988) Wenger (1998)	Situated learning (SL) is a theoretical framework that redefines learning as a social process that is intricately tied to its social context. At its core are the communities of practice (CoP), which refers to groups of individuals (in the same field of expertise or professional practice) united by a shared interest or passion, who engage in collective and collaborative learning and continued refinement of expertise through collaborative interactions and shared experiences (Wenger, 1998; Wenger et al., 2002). Wenger (1998) analyzes	Theodorakopoulos et al. (2012)

Table 7 (*continued*)

Theoretical perspectives	Foundational authors of these theoretical perspectives	Conceptual overview	Examples of articles of the SLR that discussed these theoretical perspectives
		CoPs through practice (learning by doing); community (learning by belonging); meaning (learning by experience); and identity (learning by becoming).	
Nonaka's knowledge creation theory	Nonaka (1994) Nonaka and Takeuchi (1995)	Nonaka's theory of knowledge creation, often referred to as the SECI model, is a seminal framework in the field of knowledge management. It emphasizes that knowledge is created through a continuous and dynamic interaction between two types of knowledge: tacit and explicit. The model involves four sequential modes of knowledge conversion: 1) socialization, 2) externalization, 3) combination, and 4) internalization, before returning once more to socialization. This spiral process, where each mode builds on the previous one, implies that knowledge creation is implicitly knowledge accumulation (Nonaka, 1994; Nonaka & Takeuchi, 1995).	Simbe (2022)
Public Engagement Model (PEM)		The PEM posits that scientific communication should be a bidirectional and interactive process, as opposed to a unidirectional transfer of information from scientists to the public. It recognizes the significant influence of social and psychological factors on the public's reception and interpretation of scientific information.	Getson et al. (2022)

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Table 7 (*continued*)

Theoretical perspectives	Foundational authors of these theoretical perspectives	Conceptual overview	Examples of articles of the SLR that discussed these theoretical perspectives
Triple Helix theory/Mode 1 and Mode 2 Knowledge Production	Etzkowitz and Leydesdorff (1995) Gibbons et al. (1994)	The Triple Helix theory, developed by Etzkowitz & Leydesdorff in the mid-1990s, explores the dynamic relationship between three key actors: universities, industries, and governments. Mode 1 and Mode 2 knowledge production concepts were introduced by Gibbons et al. (1994). Mode 1 research has a focus on new knowledge as defined by a set of peers within a particular discipline, whereas Mode 2 research focuses on new modes of academic activities that are cross disciplinary, outward-facing, and concerned with the problems of the milieu of practice.	Hočevar & Istenič (2014) Fongwa & Marais (2016)

Determinants related to the individual characteristics of agricultural researchers. Through this SLR, four key subcategories of determinants related to the individual attributes of agricultural researchers were identified: 1) researcher attributes and background, encompassing researchers' competencies, educational background, seniority, experience, and interdisciplinarity; 2) researcher attitudes and motivations, including their attitudes, cultural perspectives, perceptions, intentions, and motivations; 3) researcher engagement and output, which refer to their time allocation, productivity, and type of research; and 4) research teams and networking, covering research teams as well as researchers' social capital and networking abilities (see Table B.1 in Appendix B for a detailed classification).

a. **Researcher attributes and background**

Researchers' competencies

The competencies and skills of agricultural researchers in terms of transferring knowledge are key drivers for the successful dissemination of scientific research within the agricultural community (e.g., Ansari et al., 2016; Bayissa, 2015a; Getson et al., 2022; Helen et al., 2010; Ifeanyi-Obi, 2023; Karamidehkordi, 2013). These competencies encompass their ability to effectively and skillfully communicate their findings, insights, and innovations to farmers in clear, relevant, meaningful, and useful ways. The ability to convey complex scientific research in an understandable and relevant manner to farmers is innate; researchers may not possess the skills required for effective knowledge transfer. When researchers lack the necessary practical knowledge and skills, they may struggle to conduct demand-driven research that addresses real-world agricultural issues (Bayissa, 2015a). Therefore, without training, knowledge transfer is likely to be less impactful and more challenging to accomplish (Ansari et al., 2016). Through such training, researchers can refine their ability to translate tacit and complex scientific findings into languages and formats that resonate with farmers, making research more accessible and actionable (Ansari et al., 2016; Getson et al., 2022; Helen et al., 2010; Karamidehkordi, 2013).

Table 8
Other relevant theoretical perspectives.

	Resource-based view	Neo-institutional theory	Motivation theory
Main authors	Barney, 1991; Conner & Prahalad, 1996; Grant, 1996; Kogut & Zander, 1992.	DiMaggio & Powel, 1983; Scott, 1987; Zucker, 1977.	Deci & Ryan, 2000; Ryan & Deci, 2000; Gagné & Deci, 2005.
Theoretical foundations	The resource-based view (RBV) theory helps to understand the knowledge transfer process. It focuses on the relationship between internal resources, profitability, and ability of an organization to provide a sustainable competitive advantage.	This theory focuses on the institutional environment in which organizations operate. It posits that a set of values, norms, and organizational models exist outside organizations, which influence their structures and management methods (Meyer & Rowan, 1977).	According to the theory of self-determination (SDT), motivation exists along a continuum of self-determination and can be categorized into three main types: amotivation, extrinsic motivation, and intrinsic motivation.
Contributions	This theory assumes that researchers are like entrepreneurs in private companies, using many resources deployed and coordinated in the process of publishing, transferring, and commercializing research findings. As a result, researchers have access to tangible and intangible resources that differ from one researcher to another, generating heterogeneity (Landry et al., 2010; Amara et al., 2015). Such a perspective suggests that the probability of publishing and transferring the research findings to the practice milieu increases when resources are coordinated and managed appropriately.	The theory outlines three types of institutional pressures (Engwall, 2007): 1. Coercive pressures, which refer to both formal pressures (exerted by external entities such as the state, funding organizations, dedicated organizations, and government agencies) and informal pressures (practices and habits); 2. Normative pressure arising from actors outside the research institution, such as non-governmental organizations or professional associations, who establish norms, values, and expectations related to knowledge transfer; 3. Mimetic pressure arising from the imitation of performance-related standards in an uncertain context.	The self-determination theory (SDT) (Deci & Ryan, 1985) provides a useful framework for understanding individual motivation to undertake certain activities. It "focuses on types, rather than just amount, of motivation, paying particular attention to autonomous motivation, controlled motivation, and amotivation as predictors of performance, relational, and well-being outcomes" (Deci & Ryan, 2008, p. 182).
Analysis level	Organizational	Institutional	Individual

Researchers' experiences

The findings reveal that agricultural researchers' experience plays a crucial role in enhancing the transfer of scientific research to farmers (e.g., Bayissa, 2015a; Helen et al., 2010; Wheeler, 2008; Wijerathna et al.,

Table 9
Taxonomy of knowledge transfer channels from agricultural researchers to farmers.

CATEGORY NAME	DEFINITION	KNOWLEDGE TRANSFER MECHANISM IN AGRICULTURE	EXAMPLES OF AUTHORS FROM SLR	FORMAL TRANSFER MECHANISM	INFORMAL TRANSFER MECHANISM
INTERACTIVE ORAL MEDIUM					
DIDACTIC FORM	**An interactive oral medium based on the demonstration of how to effectively use research findings, as well as discussions with users of the implications of using these findings.**	**1. Direct interventions with end-users**			
		• Face-to-face contacts • Technical assistance visits • On-site advice	Faborode and Ajayi (2015) Helen et al. (2010) Karamidehkordi (2013) Larson and Duram (2000) Mgbenka et al. (2013) Theodorakopoulos et al. (2012) Wijerathna et al. (2015)	X	
		2. Group learning			
		• Workshops	Ahmadinejad (2020) Ansari et al. (2016) Duram and Larson (2001) Hočevar and Istenič (2014) Ifeanyieze et al. (2017) Larson and Duram (2000) Taheri et al. (2022) Theodorakopoulos et al. (2012) Thurner & Zaichenko (2018) Wijerathna et al. (2015)	X	
		• Organization of seminars / Symposia / conferences / Public lectures	Dirimanova & Radev (2017) Hočevar & Istenič (2014) Ifeanyi-obi & Asuquo (2023)	X	
		• Field demonstration days / Front-line demonstrations / Result demonstrations / Demonstration fields / Demonstration plots and small plot adaptive techniques	Faborode & Ajayi (2015) Kaur & Kaur (2013) Mgbenka et al. (2013)	X	
		3. Structured educational program			
		• Training programs/sessions, conducted by researchers or experts • Educational programs/Coaching sessions • Establishment of farmer training centers and farmer field schools	Ayalew and Abebe (2018) Ahmadinejad (2020) Cruz et al. (2022) Faborode & Ajayi (2015) Fongwa and Marais (2016) Getson et al. (2022) Ifeanyi-obi & Asuquo (2023) Karamidehkordi (2013) Kaur & Kaur (2013) Simbe (2022) Taheri et al. (2022)	X	
		4. Exhibitions and agricultural shows			
		• National and international exhibitions/ Farmer fairs and agricultural shows	Ahmadinejad (2020) Kaur & Kaur (2013) Dirimanova & Radev (2017)	X	
		5. On-Farm research initiatives			
		• On-farm adaptive research (OFAR) / adaptive research trials (ARTs) / On-farm participatory research	Karamidehkordi (2013) Kaur & Kaur (2013) Mgbenka et al. (2013)	X	

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Table 9 (*continued*)

CATEGORY NAME	DEFINITION	KNOWLEDGE TRANSFER MECHANISM IN AGRICULTURE	EXAMPLES OF AUTHORS FROM SLR	FORMAL TRANSFER MECHANISM	INFORMAL TRANSFER MECHANISM
DIALOGIC FORM	**An interactive oral medium based on discussion and mutual exchange mechanisms of the practical implications of the research findings and the conditions of their implementation.**	**6. Participatory activities** • Peer learning networks • Joint planning and management of research and extension initiatives • Joint evaluation activities • Participatory research activities	Ahmadinejad (2020) Cruz et al. (2022) Karamidehkordi (2013)	X	
		7. Group meetings • Group meetings / Joint meetings / Colloquiums / Committees (e.g., communities of practice, steering group meetings, inter-agency committees) • Monthly technology review meetings (MTRM) • Open communication with various stakeholders • Farmer discussion meetings	Dharmawan et al. (2023) Faborode & Ajayi (2015) Theodorakopoulos et al. (2012)	X	
		8. Forums • Experience sharing forums / Interaction forums / Feedback systems	Ayalew & Abebe (2018) Bayissa (2015a) Dirimanova & Radev (2017) Helen et al. (2010)		X
		9. One-on-One communication • Farmer-to-farmer / neighbor-to-neighbor information exchange • Personal conversations / Informal meetings	Faborode & Ajayi (2015) Ayalew & Abebe (2018) Simbe (2022) Theodorakopoulos et al. (2012)		X
TEXT-BASED MEDIUM					
THEMATIC FORM	**A written medium drawing on the writing of reports on specific themes relevant for targeted audiences.**	**10. Academic and scientific publications** • Academic publications in peer-reviewed journals / Edited proceedings • Conference papers • Annual reports • Books/monographs	Ayalew & Abebe (2018) Dharmawan et al. (2023) Duram & Larson (2001) Ifeanyi-obi & Asuquo (2023) Larson & Duram (2000) Okocha (1995) Thurner & Zaichenko (2018)	X	
		11. Informational materials • Bulletins • Brochure / Leaflets / Pamphlets • Pictorial presentations • Posters • Farm magazines • Newspapers / Newsletters	Ayalew & Abebe (2018) Dharmawan et al. (2023) Duram & Larson (2001) Faborode & Ajayi (2015) Hočevar & Istenič (2014) Ifeanyieze et al. (2017) Larson & Duram (2000)	X	
TACTICAL FORM	**A written medium based on the publication of articles in professional journals, enabling research results to be presented in a practical way and accessible to practitioners. (Illustrated report)**	**12. Technical and extension publications** • Technical reports / Technical publications • Extension guides / Extension bulletins / Extension publications	Karamidehkordi (2013) Okocha (1995)	X	
PRACTICAL FORM	**A written medium focused on the direct application and demonstration of research findings.**	**13. Policy reports** • Policy discourses	Ifeanyi-obi and Asuquo (2023)	X	
ELECTRONIC MEDIUM					
ELECTRONIC FORM	**A digital representation or format of information or communication.**	**14. Online communication platforms** • Internet/ specialized websites/ online sources	Faborode & Ajayi (2015)	X	

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Table 9 (*continued*)

CATEGORY NAME	DEFINITION	KNOWLEDGE TRANSFER MECHANISM IN AGRICULTURE	EXAMPLES OF AUTHORS FROM SLR	FORMAL TRANSFER MECHANISM	INFORMAL TRANSFER MECHANISM
			Hočevar & Istenič (2014) Larson & Duram (2000) Wheeler (2008)		
		• Social media (Facebook, Twitter, etc.)	Ifeanyi-obi & Asuquo (2023) Wheeler (2008)		**X**
		• Online events (webinars, virtual meetings, etc.)	Ifeanyi-obi & Asuquo (2023)	**X**	
		15. Mass media and digital platforms			
		• Mass media (television, radio broadcasting, telephone, etc.)	Faborode & Ajayi (2015) Ifeanyi-obi & Asuquo (2023) Ifeanyieze et al. (2017)	**X**	
		• Digital platforms (mobile applications, online portals, etc.) / Information and communication technology (ICT)	Kaur & Kaur (2013) Simbe (2022) Taheri et al. (2022)	**X**	
STRUCTURAL MEDIUM					
STRATEGIC FORM	**A structural medium based on a formal contract with specific objectives (involves formal agreements and institutional structures to facilitate knowledge transfer).**	**16. Extension and advisory services**			
		• Extension or advisory services / Brokers / Extensionists / Agricultural agencies / Intermediaries	Bayissa (2015a) Helen et al. (2010) Hočevar & Istenič (2014) Ifeanyi-obi & Asuquo (2023) Okocha (1995) Theodorakopoulos et al. (2012) Wheeler (2008)	**X**	
		17. Technology transfer structures and project development			
		• Technology transfer offices / Research and technology organizations (RTOs)	Thurner & Zaichenko (2018)	**X**	
		• Science and technology parks	Ansari et al. (2016)	**X**	
		• Incubators	Ansari et al. (2016)	**X**	
		• R&D centers / Knowledge transfer centers / Farm science center	Ahmadinejad (2020) Jarábková et al. (2019) Kaur & Kaur (2013)	**X**	
		• Creation of spin-offs and academic firms	Ansari et al. (2016) Thurner & Zaichenko (2018)	**X**	
		18. Consulting services			
		• Consulting services	Ahmadinejad (2020) Ansari et al. (2016) Wijerathna et al. (2015)	**X**	
		19. Collaborative partnerships			
		• Collaboration with non-governmental organizations (NGOs) / Collaboration with agricultural cooperatives / Collaboration with associations	Taheri et al. (2022) Theodorakopoulos et al. (2012) Wijerathna et al. (2015)	**X**	
		• Joint research projects / Collaborative projects / Development projects / Field projects / Student projects and internships	Hočevar and Istenič (2014) Ifeanyieze et al. (2017) Karamidehkordi (2013) Wijerathna et al. (2015)	**X**	

2015). Experience in knowledge transfer activities within the agricultural community is a strong predictor of researchers' future engagement in such activities as they recognize their value and impact (Wijerathna et al., 2015). Moreover, experienced researchers with a background in knowledge transfer activities are better equipped to address practical agricultural issues and formulate solutions aligned with the needs of farming communities (Bayissa, 2015a).

Researchers' educational background and seniority

The findings reveal that researchers' educational backgrounds play an important role in shaping their approach to knowledge transfer (e.g., Cruz et al., 2022; Wheeler, 2008). Researchers with advanced tertiary education approach their work with greater analytical rigor and open-mindedness, enabling them to critically assess complex challenges and develop innovative solutions (Cruz et al., 2022). Researchers with broader educational backgrounds may be better prepared to appreciate the practical challenges faced by farmers and other local stakeholders

(Wheeler, 2008), fostering more relevant knowledge transfer activities, which researchers are more inclined to adjust to meet farmers' specific needs and conditions. Moreover, the researchers' seniority or academic rank significantly influences the intensity and effectiveness of this knowledge transfer. Moving up the academic ladder, they gain greater experience and resources, which enhances their capacity for effective knowledge transfer (Duram & Larson, 2001).

Researchers' interdisciplinarity

Scientific discipline influences the nature of the knowledge being transferred, thereby shaping the process of transferring agricultural research (e.g., Duram & Larson, 2001; Maas et al., 2021). Furthermore, the agricultural sector faces challenges that require insights from a wide range of disciplines. Interdisciplinarity plays a crucial role in facilitating knowledge transfer from researchers to farmers (Maas et al., 2021). Researchers from different disciplines in the agricultural field have a diverse range of perspectives, allowing them to approach complex challenges from multiple angles. In agriculture, where the challenges are multifaceted, this multidisciplinary approach not only enhances problem-solving abilities, but also promotes a more efficient approach to addressing these issues.

a. **Researcher attitudes and motivations**

Researchers' attitudes, cultures and perceptions

The SLR finds that the divergent perspectives, cultures, and interests of researchers and farmers can significantly exacerbate challenges in the knowledge transfer process (Ansari et al., 2016; Bayissa, 2015b; Maas et al., 2021). Researchers who often prioritize theoretical frameworks and pursue new scientific results may find themselves at odds with farmers who are more concerned about practical and experience-based solutions. Moreover, researchers' attitudes towards farmers' knowledge play a crucial role in the knowledge transfer process (Cruz et al., 2022). Some researchers commonly view farmers' knowledge as inferior or less valuable than scientific knowledge (Cruz et al., 2022). These prejudices and perceptions of inferiority can lead researchers to undervalue farmers' practical insights grounded in years of experience and a deep understanding of specific agricultural contexts (Cruz et al., 2022).

Researchers' intentions and motivations

Researchers' intentions and readiness to transfer their research results to farmers are essential components that influence the knowledge transfer process (Bayissa, 2015b; Taheri et al., 2022). As advocated by many studies in the SLR, researcher motivation is a critical determinant of the success of knowledge transfer activities (e.g., Ahmadinejad, 2020; Bayissa, 2015b; Faborode & Ajayi, 2015; Helen et al., 2010; Ifeanyi-obi & Asuquo, 2023; Karamidehkordi, 2013; Wijerathna et al., 2015). Specifically, when researchers are not adequately motivated by their institutions (whether through financial rewards, opportunities for career advancement, material gains, public recognition, or honors), they are less inclined to dedicate the necessary time, resources, and effort to engaging with farmers and other potential agricultural users of their research (Ifeanyi-obi & Asuquo, 2023; Okocha, 1995). This challenge is compounded by the meritocratic structure prevalent in universities (Anzivino & Cannito, 2024; Soysal et al., 2024), which often prioritizes specific measurable outputs such as publications, citations, and the acquisition of research grants (Hočevar & Istenič, 2014).

In addition, subjective norms shaped by the perception of approval from colleagues or superiors within an institution can significantly influence a researcher's decision to participate in knowledge-transfer activities (Wijerathna et al., 2015). When researchers believe that their peers and the academic institutions value and support their engagement in knowledge transfer activities, they are more likely to feel motivated to prioritize such activities (Ahmadinejad, 2020; Bayissa, 2015b). Personal satisfaction is a key driver motivating academics to engage in knowledge transfer (Wijerathna et al., 2015). When researchers experience a profound sense of fulfillment from seeing their research output, they are not only more likely to participate in these activities but also more committed to sustaining their involvement over time. Similarly, researchers who approach outreach activities positively and view them as enjoyable and inherently valuable are significantly more likely to participate actively (Wijerathna et al., 2015). By perceiving these activities as opportunities to connect with the practical side, address real-world challenges, and contribute to the advancement of agriculture, this participation is fueled by genuine enthusiasm rather than external pressure.

The findings align with a substantial body of literature highlighting the dual nature of motivation, encompassing both intrinsic and extrinsic factors, in influencing researcher engagement in knowledge transfer. For instance, Lam's (2011) framework provides valuable insights into how different motivational drivers affect a researcher's participation in these activities. According to Lam (2011), researchers' motivations can be divided into three distinct categories: intrinsic satisfaction, derived from intellectual curiosity (puzzle); financial incentives and economic rewards (gold); and the pursuit of professional recognition, reputation enhancement, and career progression (ribbon). The puzzle motivation is linked to intrinsic motivators, while the gold and ribbon motivations are associated with extrinsic motivators.

a. **Researcher engagement and output**

Researchers' time allocation

According to several studies, the allocation of time across teaching, research, and dissemination activities plays a pivotal role in determining the effectiveness of knowledge transfer within the agricultural sector (Faborode, 2015; Getson et al., 2022; Larson & Duram, 2000; Wijerathna et al., 2015). Researchers' ability to effectively transfer knowledge to farmers hinges not only on their expertise but also on the availability of sufficient time to meaningfully engage in these activities (Larson & Duram, 2000). Heavy workloads for researchers, including teaching, research, and administrative duties, may create significant time constraints (Larson & Duram, 2000). The constant pressure to fulfill the expectations associated with these multiple roles often results in the de-prioritization of activities that do not yield immediate academic outputs.

Research type

The effectiveness of knowledge transfer to farmers is significantly influenced by the type of research conducted by agricultural researchers (e.g., Ahmadinejad, 2020; Bayissa, 2015a; Mgbenka et al., 2013; Simbe, 2022). Contemporary agricultural research faces a significant disconnect between the practical needs of farmers and the research priorities of academic institutions (Bayissa, 2015a). This gap arises largely from the type of research, which often tends to be theoretical and disconnected from real-world agricultural challenges (Bayissa, 2015a).

Researchers, driven by a combination of intrinsic motivations and external incentives, tend to focus on producing high-impact publications that often emphasize scientific rigor and novelty over practical relevance (Hočevar & Istenič, 2014). This focus on theoretical contributions, while valuable in advancing scientific understanding, often results in research outputs too abstract to be of immediate use in addressing farmers' challenges (Bayissa, 2015a; Hočevar & Istenič, 2014). Unlike basic research, applied research is explicitly designed to address practical problems and provide solutions that can be implemented in real-world contexts. However, despite its importance, applied research is frequently undervalued in academia and lacks the recognition and support it deserves (Hočevar & Istenič, 2014). Applied research projects, which may yield immediate and tangible benefits for farmers, are often judged by the same criteria as basic research, despite their different objectives (Hočevar & Istenič, 2014).

Researchers' productivity

The authors found that researchers' productivity, often measured by academic publications and citations, is a critical factor in the knowledge-transfer process (e.g., Fongwa & Marais, 2016; Ifeanyi-obi & Asuquo, 2023). According to Fongwa and Marais (2016), effective

knowledge transfer relies heavily on the researchers' capacity to produce high-quality research. Ifeanyi-obi & Asuquo (2023) highlight the importance of publishing articles as a major activity in the transfer of agricultural research.

a. **Researcher team and networking**

Research team

The size of the research team significantly influences the knowledge transfer process. For instance, Thurner & Zaichenko (2018) highlight the crucial role of staff numbers, particularly within Research and technology organizations, and explain how staff expansions or reductions directly impact the effectiveness of technology transfer activities. When a research team has a large number of members, it benefits from a diverse range of skills, expertise, and backgrounds. A larger team also allows a more efficient distribution of workload, ensuring that the responsibilities associated with knowledge transfer are managed effectively.

Researchers' social capital and networking

Numerous studies underscore the pivotal role of researchers' social capital in facilitating knowledge transfer within the agricultural sector (e.g., Ahmadinejad, 2020; Bayissa, 2015b, 2015c; Cruz et al., 2022; Dirimanova & Radev, 2017; Faborode & Ajayi, 2015; Fongwa & Marais, 2016; Ifeanyi-obi & Asuquo, 2023; Kaur & Kaur, 2013; Larson & Duram, 2000). Strong social capital accelerates the transfer of information from agricultural researchers to farmers. When researchers forge strong connections with agricultural extensionists, farmers, policymakers, and other stakeholders, dissemination of scientific findings becomes more efficient (Fongwa & Marais, 2016; Ifeanyi-obi & Asuquo, 2023; Mgbenka et al., 2013). By contrast, poor coordination or limited interaction and communication between researchers and other agricultural stakeholders can be detrimental to the transfer and adoption of research (Bayissa, 2015b; Cruz et al., 2022; Faborode & Ajayi, 2015; Fongwa & Marais, 2016; Mgbenka et al., 2013).

The success of knowledge transfer in agriculture hinges on the establishment of effective communication channels that foster interactions between researchers and farmers (Duram & Larson, 2001; Larson & Duram, 2000; Simbe, 2022). Communication in agricultural research should be adapted to fit the farmers' context, ensuring it is understandable, unambiguous, contextually relevant, and directly applicable to their needs (Theodorakopoulos et al., 2012). Trust in collaborative networks is a fundamental pillar of success (e.g., Ahmadinejad, 2020; Ansari et al., 2016; Fongwa & Marais, 2016; Jarábková et al., 2019; Theodorakopoulos et al., 2012). For effective knowledge transfer, farmers must know that researchers and their affiliated institutions are committed to transparency and the pursuit of shared benefits.

Determinants related to the organizational context in universities/research centers. The SLR helped identify four determinant subcategories related to the organizational context prevailing in universities and research centers: 1) university/research center size, 2) university culture, 3) university funding and infrastructure, and 4) university research networks.

University/Research center size

The impact of university size on agricultural knowledge transfer was highlighted as a significant factor in some studies. The size of an institution, often quantified by the number of research staff members or the presence of a dedicated knowledge and technology transfer office, can substantially influence the effectiveness of knowledge transfer activities (Thurner & Zaichenko, 2018). Larger universities and research institutions tend to possess more extensive expertise, specialized support structures, greater resources, and a broader knowledge base. These attributes collectively enhance a university's capacity to effectively disseminate agricultural research findings and technologies to the agricultural community.

University culture

Universities' culture and strategic orientation significantly influence how research is transferred and applied in practical contexts (Fongwa & Marais, 2016; Wijerathna et al., 2015). A university's academic culture, shaped by its values and norms, can facilitate or hinder knowledge transfer to the agricultural community. When a university does not allocate sufficient resources or lacks a clear policy that promotes and supports knowledge transfer activities, it reflects a cultural orientation that may not fully recognize the importance of engagement beyond academic circles (Fongwa & Marais, 2016).

Often, within universities, the criteria used for faculties' promotions typically emphasize metrics such as publication achievements and citation counts, with far less recognition given to activities like transferring research or working with non-academic stakeholders (Hočevar & Istenič, 2014). The "publish or perish" culture in universities means that activities that are seen as peripheral to publication, such as engaging with non-academic stakeholders or focusing on knowledge transfer, particularly in the agricultural sector, are often deprioritized (Hočevar & Istenič, 2014).

University funding and infrastructure

A key factor influencing the effectiveness of knowledge transfer in agriculture is the level of investment in financial and material resources (Ahmadinejad, 2020; Ansari et al., 2016; Duram & Larson, 2001; Faborode & Ajayi, 2015; Fongwa & Marais, 2016; Ifeanyi-obi & Asuquo, 2023; Ifeanyieze et al., 2017; Larson & Duram, 2000). Research institutions rely on funding from various public and private sources, including foundations, government councils and agencies, nonprofit organizations, and private entities. Competitive funding mechanisms drive institutions to prioritize applied research with tangible pathways for commercialization (Thurner & Zaichenko, 2018). By contrast, institutions that receive a large share of their budget from public funds may lean towards basic research (Duram & Larson, 2001; Thurner & Zaichenko, 2018). Short-term funding limits researchers' ability to adapt agricultural research to the diverse and evolving needs of different regions (Duram & Larson, 2001). Insufficient funding leads to challenges in providing the material, technical, and logistical resources required to facilitate successful technology transfer (Faborode & Ajayi, 2015). In addition to financial constraints, inadequate infrastructure such as poor transportation or limited information and communication technology (ICT) resources presents a significant barrier to knowledge transfer in agriculture (Ahmadinejad, 2020; Ansari et al., 2016; Fongwa & Marais, 2016; Helen et al., 2010; Ifeanyi-obi & Asuquo, 2023; Ifeanyieze et al., 2017; Larson & Duram, 2000; Wijerathna et al., 2015). Effective communication and interaction with farmers often require robust infrastructure, including efficient and reliable transportation systems, advanced ICTs, and well-equipped research facilities.

University research networks

University networks are an important determinant for the success of knowledge transfer initiatives for the agricultural sector (Ayalew & Abebe, 2018; Hočevar & Istenič, 2014; Larson & Duram, 2000). Universities often engage with a diverse range of external stakeholders such as farmers, agricultural extension services, government agencies, and other relevant stakeholders. However, the effectiveness of these networks is often impaired by limited interinstitutional collaboration (Hočevar & Istenič, 2014; Ifeanyi-obi & Asuquo, 2023). The absence of well-coordinated collaborations across different institutions creates barriers to effective knowledge transfer (Hočevar & Istenič, 2014). This lack of coordination hampers the exchange of crucial insights and leads to a top-down linear approach that often fails to address the complex and evolving needs of agricultural communities.

Determinants related to the external environment. The effectiveness of the knowledge transfer process is influenced by a range of contextual determinants (e.g., Dharmawan et al., 2023; Fongwa & Marais, 2016;

Helen et al., 2010), which can be divided into socio-cultural and institutional/political determinants. Previous SLRs have argued that one of the critical determinants of effective knowledge transfer is the ability to adapt activities to the unique cultural and socioeconomic conditions of different regions (Cruz et al., 2022; Getson et al., 2012; Simbe, 2022). This is particularly important because knowledge transfer is highly context-dependent; a one-size-fits-all approach is unlikely to effectively address diverse contexts and needs. Consequently, the effectiveness of knowledge transfer activities is closely linked to their alignment with the characteristics of the agricultural community and targeted regions (Cruz et al., 2022). Without this contextual sensitivity, even the most innovative and well-intentioned knowledge transfer initiatives risk failing to resonate with local populations, diminishing their potential impact. Cultural barriers arising from differences in cultural and social backgrounds may severely hinder the transfer of knowledge to farmers from various groups or cultural backgrounds (Fongwa & Marais, 2016). These barriers also intensify social and territorial inequalities (Faist, 2010). Effective knowledge transfer depends, among other factors, on addressing cultural barriers (such as by developing participatory communication platforms (Dharmawan et al., 2023) and building trust and collaborative ties between researchers and farmers (Fongwa & Marais, 2016; Jarábková, 2019; Theodorakopoulos et al., 2012)).

Institutional and political determinants, along with sociocultural determinants, play a key role in the transfer of scientific agricultural research (Ansari et al., 2016; Bayissa, 2015b; Getson et al., 2022; Helen et al., 2010; Ifeanyi-obi & Asuquo, 2023; Mgbenka et al., 2013). Institutions characterized by rigid structures and complex administrative processes often create significant barriers to the efficient transfer of research findings (Faborode & Ajayi, 2015; Ifeanyi-obi & Asuquo, 2023). Government investment has also emerged as a determining factor

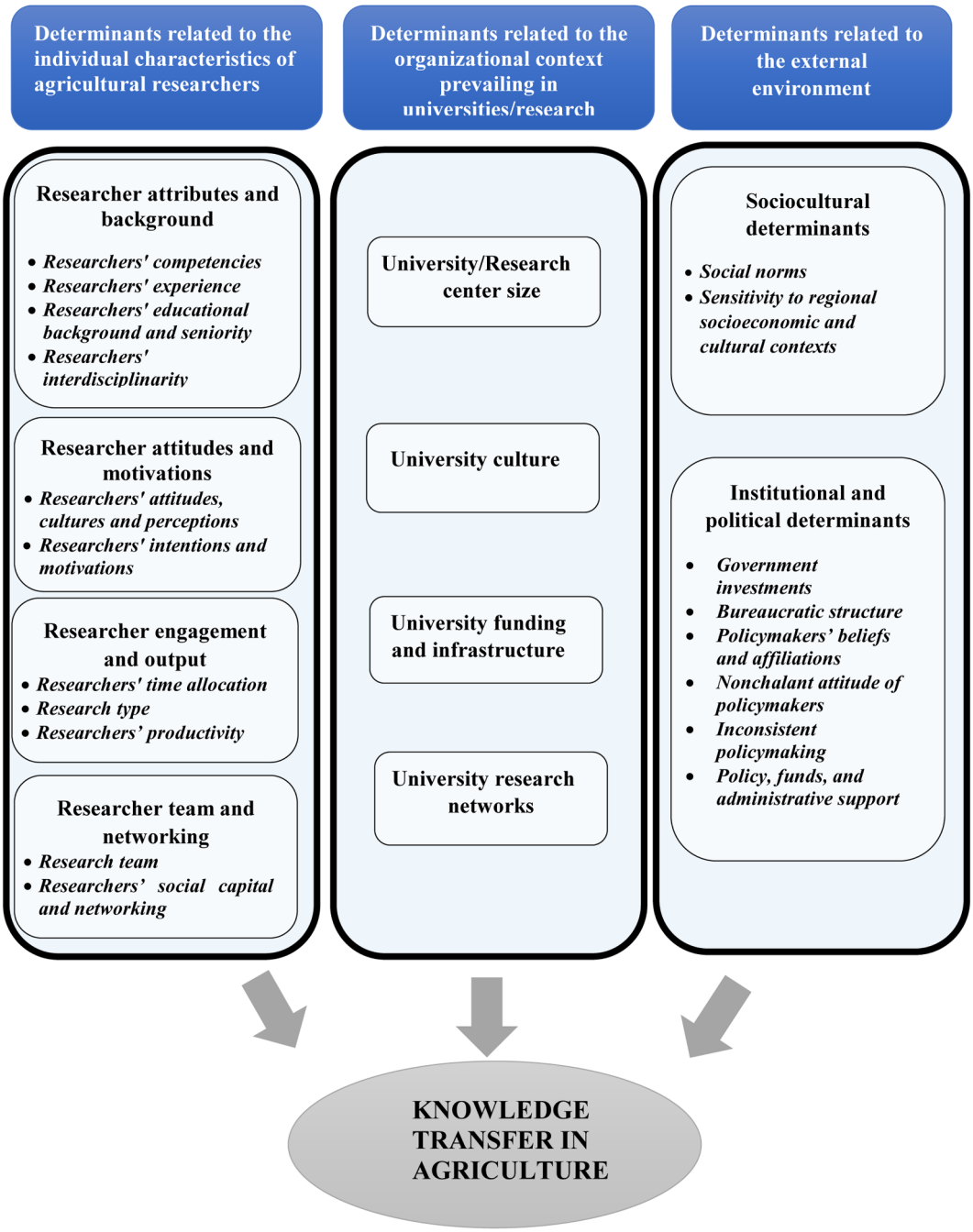

Fig. 3. Integrative conceptual framework of agricultural knowledge transfer and its determinants.

in successful transfers (Duram & Larson, 2001). Political barriers that are multifaceted and include ideological biases (Getson et al., 2022), policy apathy (Ifeanyi-obi & Asuquo, 2023), misaligned strategies, and inconsistent support (Ansari et al., 2016) add another layer of complexity.

The transfer of scientific agricultural research can also be significantly influenced by policymakers' political beliefs and affiliations (Getson et al., 2022). Political ideologies influence the allocation of resources, dictating which research areas and knowledge transfer initiatives receive priority (Getson et al., 2022). Another significant impediment is the lack of enthusiasm or active disinterest among policymakers (Bayissa, 2015b; Ifeanyi-obi & Asuquo, 2023). When policymakers neglect to integrate research findings into policy frameworks, the entire process of knowledge transfer is hampered, resulting in missed opportunities for innovation and tangible improvement. The apathy of policymakers creates a gap between research and practical implementation, leading to stagnation in policy development that could otherwise optimize the knowledge-transfer process. Finally, the absence of a clear and well-defined vision coupled with the absence of proper policies, laws, and regulations or the implementation of inappropriate policies and programs also acts as a barrier to effective knowledge transfer (Ansari et al., 2016; Bayissa, 2015b; Getson et al., 2022; Helen et al., 2010; Mgbenka et al., 2013).

An integrative conceptual framework for effective knowledge transfer in agriculture

To consolidate the main findings of the SLR on the determinants of knowledge transfer from agricultural researchers to farmers, an integrative conceptual framework was developed. The resulting framework, illustrated in Fig. 3, identifies the principal determinants that significantly explain the knowledge-transfer process from the perspective of agricultural researchers. These were categorized into individual, organizational, and environmental determinants. In individual determinants, the SLR identified 11 subcategories related to the characteristics of agricultural researchers. These encompass key attributes, such as competencies, interdisciplinarity, experience, and time allocation. Additionally, factors such as the type of research conducted, size of the research team, educational background and seniority, research productivity, social capital, and networking, along with the researchers' attitudes, perceptions, intentions, and motivations, all play significant roles in explaining knowledge transfer within the agricultural sector. In organizational determinants, we identified four key subcategories that influence knowledge transfer within universities and research centers. The size of the institution, prevailing organizational culture, availability of funding and infrastructure, and strength of research networks are all significant determinants. Lastly, environmental determinants, encompassing institutional, political, and sociocultural factors, contribute to explaining the effectiveness of knowledge transfer activities within the agricultural sector.

Contributions of this study

Theoretical contributions

To the best of our knowledge, a comprehensive mapping review to help consolidate and synthesize the existing body of knowledge on transfer of agricultural research has been lacking. This SLR on transfer of agricultural research knowledge to farmers and its levers and obstacles enabled the identification of patterns, trends, and gaps in literature. Second, there is still a limited understanding of how agricultural researchers transfer their research results to practitioners in the agricultural milieu. This study proposes an original taxonomy of knowledge transfer channels based on two dimensions: the type of transfer medium (interactive oral or textual support) and the form of transfer (didactic, dialogic, tactical, practical, thematic, electronic, or strategic). Third, this study developed an integrative, evidence-based framework based on the relevant studies to improve our understanding of the levers and barriers that may explain differences in agricultural researchers' engagement in knowledge transfer. This framework categorizes the determinants into three significant categories related to the: 1) individual characteristics of agricultural researchers, 2) prevailing organizational context of research institutions, and 3) external environment. This integrative conceptual framework, derived from the first SLR on the transfer of agricultural research to producers, represents a substantial conceptual contribution. Finally, for agricultural researchers, this study provides a research agenda that identifies underexplored lines of research and may serve as a foundation for future research,

Practical contributions

Beyond the theoretical realm, the results of this study will illuminate agricultural practitioners and decision-makers regarding key determinants that can be targeted to enhance the knowledge transfer process. The results will generate actionable insights relevant not only to universities, researchers, and knowledge and technology transfer organizations (KTTOs) but also to various stakeholders within the agricultural sector. This encompasses extension and agricultural advisory agencies, agricultural unions, government organizations, and agencies involved in promoting agricultural practices that value cutting-edge research and innovation. A comprehensive understanding of the levers and barriers that may encourage or discourage bridging the gap between researchers and farmers will guide stakeholders in effectively fostering practice-oriented research transfer among farmers, designing impactful knowledge-transfer programs, and fine-tuning policies.

Towards a research agenda for the future

Overall, the proposed research agenda provides a starting point for further analysis to address several shortcomings in literature and opens the opportunity for more high-quality studies to reduce or close the gap between academics and farmers. Specifically, our review and analysis identify several gaps and shortcomings that deserve further investigation. Six of these are of particular interest and may provide promising research opportunities.

- *Disentangling research production from research transfer*

Without exception, the reviewed articles failed to differentiate between knowledge production and knowledge transfer processes. Several significant contributions to the topic of knowledge transfer from research producers to potential users in the practice milieu have highlighted the importance of disentangling the problems and issues related to each process regarding the knowledge transfer gap. For instance, Shapiro et al. (2007) used the metaphors of "lost in translation" and "lost before translation" to refer, respectively, to knowledge production problems and knowledge transfer problems. Amara et al. (2019) drew on Stoke's model (1997) to construct four profiles of researchers by crossing two variables reflecting the researchers' orientation towards the production of knowledge for the basic understanding of problems or towards practical users' needs. Consequently, an interesting contribution to the advancement of knowledge on agricultural knowledge transfer will be to disentangle the factors impairing the bridging of the gap between agricultural researchers and farmers according to the knowledge production and transfer processes.

- *Grounding the determinants of knowledge transfer in a conceptual framework*

Studies that have attempted to identify the determinants of knowledge transfer from agricultural researchers to farmers suffer from an underdevelopment of theoretical grounding (e.g., Ansari et al., 2016; Kaur & Kaur, 2013; Maas et al., 2021; Thurner & Zaichenko, 2018). A

majority of the selected papers (20 articles, or 66.66 %) did not explicitly refer to models or theoretical approaches. This lack of a sound theoretical background hinders the full exploitation of the relationship between knowledge transfer and its determinants. As a theoretical contribution to the advancement of knowledge, an integrative conceptual framework is proposed that categorizes the determinants of agricultural knowledge transfer identified through the data extraction procedure of the systematic literature review into meaningful categories. Additionally, the need to better anchor the selection of the determinants of agricultural knowledge transfer within theoretical frameworks is emphasized, along with the importance of testing hypotheses based on the predictions of these theories.

- *Proposing a taxonomy of knowledge transfer channels*

In the articles studied, we found no classification or grouping of the knowledge transfer channels used by agricultural researchers to reach farmers. To address this gap, an original taxonomy of knowledge transfer channels is proposed, inspired by Jbilou (2010) and based on two dimensions: type of medium and form of transfer. However, this taxonomy warrants empirical testing.

- *Refining the knowledge transfer and its determinants' measures*

For articles advocating quantitative approaches, the SLR found an underutilization of widely recognized and validated constructs and indicators to measure knowledge transfer and its determinants. Literature appears to be less receptive to methodologies developed in other disciplines. For instance, several well-known constructs developed by researchers from various fields for measuring knowledge transfer from researchers to practitioners have been identified (e.g., Arza & Carattoli, 2017; Landry et al., 2001; Lawson et al., 2019; Prado-Gascó et al., 2020, etc.). There is an urgent need to take advantage of existing empirical material from other research fields to develop constructs and indicators that consider the peculiarities of knowledge transfer in agriculture.

- *Taking into account the peculiarities of research fields and disciplines*

Overall, empirical studies on knowledge transfer have shown that disciplines matter and that researchers involved in certain disciplines are more likely to engage in knowledge transfer and other research activities, such as publication in scholarly journals, patenting, and spin-off creation than their counterparts from other disciplines (Landry et al., 2007; Leydesdorf & Shin, 2011; Mugabushaka et al., 2016; Radicchi & Castellano, 2012; Rhaiem & Amara, 2020). Future research should consider the peculiarities and publication conventions of different disciplines. Many fields are driven by traditional systems that reward publications in prestigious journals and high bibliometric metrics (Amara et al., 2015). This system has implications for other research activities, including the transfer of knowledge to practical applications.

- *Consolidating the pool of empirical studies*

With a few exceptions (e.g., Ansari et al., 2016; Ifeanyi-obi & Asuquo, 2023; Okocha, 1995), the identification of the determinants of knowledge transfer was rarely the main objective of the articles analyzed. Therefore, more empirical studies will be needed to explain knowledge transfer in agriculture. One can diversify analytical methods by incorporating asymmetrical methods such as qualitative comparative analysis (QCA) (Ragin, 2006, 2009). Unlike correlational methods, such as regression, QCA offers the advantage of identifying multiple configurations of necessary and sufficient conditions that lead to the same outcome—in this case, transfer of knowledge to practical applications. This alternative method is being increasingly utilized across various disciplines (e.g., health, management, and the environment).

Limitations and concluding remarks

The findings of the SLR should be considered in light of some limitations. The first is the heterogeneity across studies and the risk of data removal from specific contexts. This heterogeneity can manifest in various aspects, including differences in the methodologies used, study designs, reported outcomes, and content. This could lead to incomplete interpretations and a potential loss of overall perspective when synthesizing data from diverse contexts. The second stems from predefined inclusion and exclusion criteria. Although English is the predominant language used in the scientific domain, the decision to exclude contributions in other languages led to the omission of a substantial corpus of relevant articles not written in English. The third limitation is the exclusion of grey literature in the form of books (and book chapters), essays, master's theses, doctoral theses, research notes, dissertations, and conference proceedings. The focus was specifically on peer-reviewed papers, which led to the omission of potentially valuable findings published in alternative scientific outlets. This decision may have led to the overlooking of relevant documents that could have provided further contributions. Additionally, the exclusion of conceptual studies is another significant limitation. Conceptual or theoretical studies, if included, could provide a solid theoretical foundation and broader perspective, thereby augmenting the depth and richness of our analysis.

Notwithstanding these limitations, this SLR is the first to comprehensively analyze the state-of-the-art research on knowledge transfer from agricultural research to farmers. The findings offer a promising outlook for further research.

CRediT authorship contribution statement

Sarra Ben Farah: Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Nabil Amara:** Validation, Supervision, Resources, Project administration, Methodology.

Appendix A

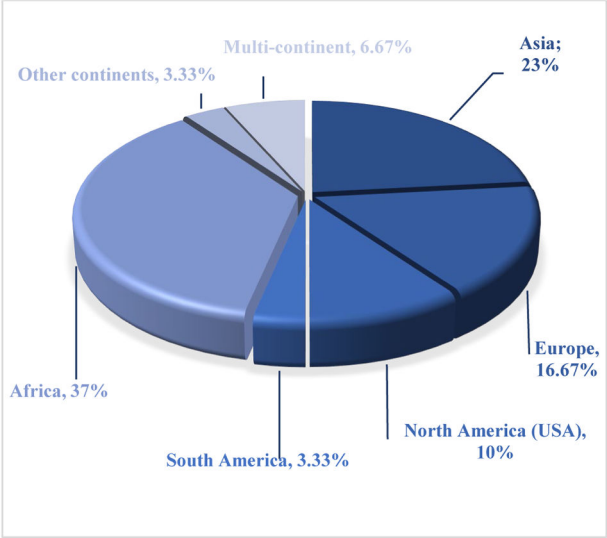

Fig. A.1. Distribution of selected articles by major regions.

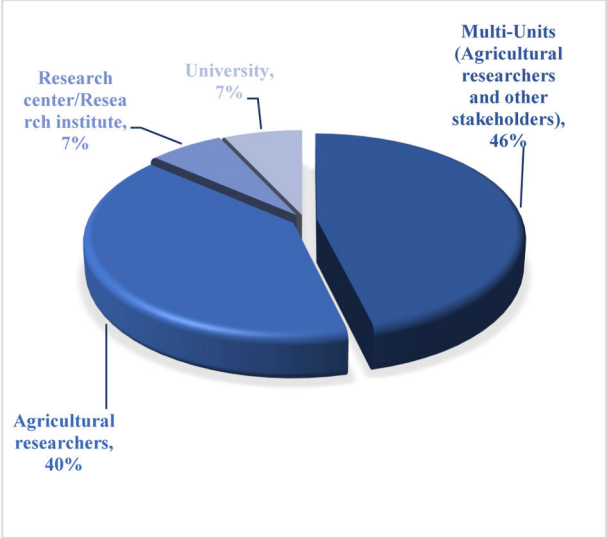

Fig. A.2. Distribution of selected articles by unit of analysis.

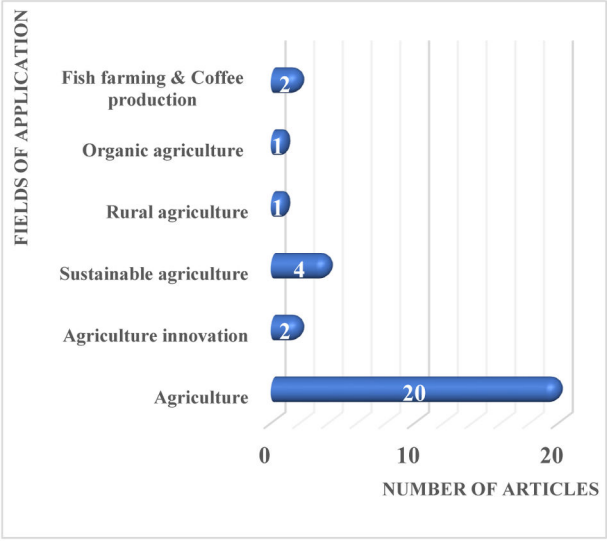

Fig. A.3. Distribution of selected articles by field of application.

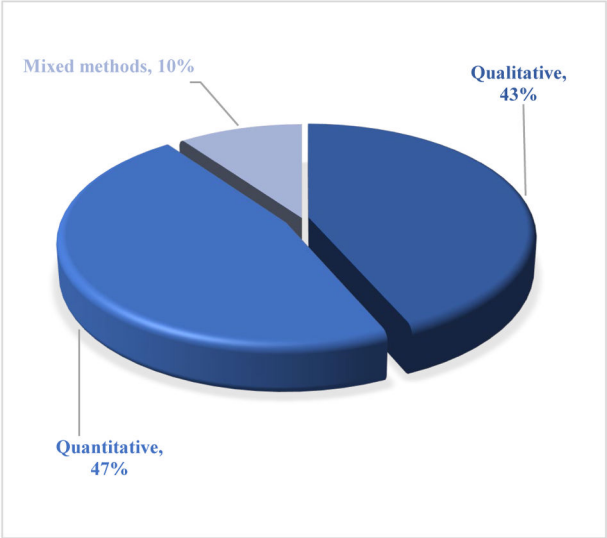

Fig. A.4. Distribution of selected articles by type of methodological approach (empirical trend).

Appendix B

Table B.1
Classification of the determinants of knowledge transfer from agricultural researchers to farmers.

DETERMINANTS	FACTORS	SUB-FACTORS	DESCRIPTION	EXAMPLES OF AUTHORS FROM THE SLR
Determinants related to the individual characteristics of agricultural researchers				
Determinants related to the individual characteristics of agricultural researchers	Researchers' competencies	Training	Training researchers is crucial for enhancing the transfer of knowledge to farmers.	Ahmadinejad (2020) Ansari et al. (2016) Getson et al. (2022) Helen et al. (2010) Ifeanyi-obi and Asuquo (2023) Karamidehkordi (2013)
		Skills	Researchers with substantial skills and expertise play a pivotal role in the effective commercialization of research findings.	Ansari et al. (2016) Bayissa (2015a)
	Researchers' interdisciplinarity	Multidisciplinary approaches/ Transdisciplinary approaches	Multidisciplinary approaches offer breadth and integration, leading to more holistic and impactful solutions.	Duram and Larson (2001) Maas et al. (2021)
	Researchers' experience	Researchers' prior engagement in knowledge transfer activities	Researchers who have previous positive experience in knowledge transfer activities are more likely to engage in similar future activities.	Bayissa (2015a) Helen et al. (2010) Wheeler (2008) Wijerathna et al. (2015)
	Researchers' time allocation	Time constraints in conducting knowledge transfer activities	Researchers often face heavy workloads that encompass teaching responsibilities, ongoing research projects, and administrative duties.	Larson & Duram (2000)
			Time constraints manifest as restricted availability for researchers to engage in effective communication and collaboration.	Faborode (2015) Getson et al. (2022) Wijerathna et al. (2015)
	Research type	Types of research conducted (basic or fundamental research, applied research)	Basic research can be too abstract and not immediately useful for solving practical agricultural issues. Basic research frequently fails to meet farmers' needs because farmers are not sufficiently involved in identifying research problems. Applied research is often undervalued and lacks adequate support for practical implementation.	Bayissa (2015a) Hočevar & Istenič (2014)
		Quality and relevance of research	High-quality and relevant research, aligned with farmers' practical needs, is essential for effective knowledge transfer to farmers. Research must address practical and timely	Bayissa (2015c) Dharmawan et al. (2023) Mgbenka et al. (2013)

(*continued on next page*)

Table B.1 (*continued*)

DETERMINANTS	FACTORS	SUB-FACTORS	DESCRIPTION	EXAMPLES OF AUTHORS FROM THE SLR
			issues faced by farmers to be considered relevant.	
		Integration of scientific research into policy and practice	For scientific research to have actionable outcomes, it needs to be effectively integrated into agricultural policy and practice.	Dharmawan et al. (2023)
	Research team	Size of the research team	Larger research teams benefit from a broader range of skills and expertise, facilitating more effective knowledge transfer.	Thurner & Zaichenko (2018)
	Researchers' educational background and seniority	Educational background	Researchers with advanced education tend to have a more analytical and open-minded approach, enhancing the effectiveness of knowledge transfer.	Cruz et al. (2022) Wheeler (2008)
		Seniority	As researchers progress in their academic careers, they tend to have greater experience and resources, which can enhance their capacity for effective knowledge transfer.	Duram & Larson (2001)
	Researchers' productivity	High research productivity	Researchers' productivity, measured by publications and citations, is a critical factor in the knowledge transfer process, though it should be paired with effective dissemination.	Fongwa & Marais (2016) Ifeanyi-obi & Asuquo (2023)
	Researchers' social capital and networking	Coordination among stakeholders	Synergy/linkage between researchers, farmers, policymakers, extension workers, and other stakeholders is essential for addressing agricultural challenges. Duration of relationships: Establishing long-term relationships between farmers and research institutions can enhance trust and facilitate ongoing collaboration. Involvement of the private sector can provide additional resources.	Ahmadinejad (2020) Ansari et al. (2016) Ayalew & Abebe (2018) Bayissa (2015a) Bayissa (2015c) Dirimanova & Radev (2017) Duram & Larson (2001) Faborode & Ajayi 92, 015) Fongwa & Marais (2016) Helen et al. (2010) Ifeanyi-obi & Asuquo (2023) Ifeanyieze et al. (2017) Kaur and Kaur (2013) Larson & Duram (2000) Mgbenka et al. (2013) Wijerathna et al. (2015)
		Effective communication channels and platforms	Utilization of effective communication methods makes agricultural research engaging and maximizes its reach among farmers.	Ayalew & Abebe (2018) Dharmawan et al. (2023) Fongwa & Marais (2016) Getson et al. (2022) Larson and Duram (2000) Maas et al. (2021) Okocha (1995) Theodorakopoulos et al. (2012)
		Trust between researchers and farmers	Initial mistrust between researchers and farmers hinders open dialogue.	Ahmadinejad (2020) Dirimanova & Radev (2017) Fongwa & Marais (2016) Jarábková et al. (2019) Theodorakopoulos et al. (2012)
	Researchers' attitudes, values and perceptions	Differences in perceptions	Researchers' and farmers' differing priorities and perspectives can exacerbate the challenges in the knowledge transfer process.	Ifeanyieze et al. (2017) Bayissa (2015c) Jarábková et al. (2019) Maas et al. (2021) Simbe (2022)
		Prejudices and stereotypes Perception of Knowledge: Perception of inferiority	Negative stereotypes about farmers significantly impede the exchange of knowledge. Some researchers perceive farmers'	Cruz et al. (2022)

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Table B.1 (*continued*)

DETERMINANTS	FACTORS	SUB-FACTORS	DESCRIPTION	EXAMPLES OF AUTHORS FROM THE SLR
			knowledge as inferior, which can hinder the recognition of valuable practical insights.	
	Researchers' intentions and motivations	Researchers' intentions	Readiness and willingness of agricultural researchers to disseminate knowledge and technologies among farmers	Bayissa (2015b) Taheri et al. (2022)
		Researchers' motivations: Intrinsic and extrinsic motivations	Incentives that drive researchers to conduct knowledge transfer activities (self-development, personal satisfaction, recognition from academic institutions, financial motivations, encouragement from peers, etc.).	Ahmadinejad (2020) Bayissa (2015b) Ifeanyi-obi & Asuquo (2023) Faborode & Ajayi (2015) Karamidehkordi (2013) Helen et al. (2010) Wijerathna et al. (2015)
Determinants related to the organizational context in universities/research centers				
Determinants related to the organizational context in universities/research centers	University/Research center size	Number of research staff Existence of a technology transfer office (TTO)	Larger universities possess greater resources, support structures, and expertise, enhancing their capacity for effective knowledge transfer.	Thurner & Zaichenko (2018)
	University culture	The university culture does not prioritize the practical application and commercialization of research	Limited support for commercialization activities university culture and norms do not support or prioritize knowledge transfer activities. Undervaluation of knowledge transfer efforts: researchers' efforts to transfer knowledge are undervalued compared to their research outputs. Absence of regular assessment of the knowledge transfer activities.	Hočevar & Istenič (2014) Wijerathna et al. (2015)
		The emphasis on research excellence	The emphasis on research excellence and the intense pressure from universities to publish in prestigious international journals affect researchers' efforts to transfer their findings into practical agricultural applications. Researchers, primarily evaluated on their scientific output, are less incentivized to engage in knowledge transfer activities.	
	Institutional policy	Absence of a clear university policy towards promoting and supporting knowledge transfer activities	Without adequate policies, laws, and regulations to support knowledge transfer, the process of moving research into practical use can be cumbersome and fraught with obstacles.	Bayissa (2015c) Wijerathna et al. (2015)
		Bureaucratic structures	The bureaucratic nature of agricultural institutions, characterized by complex administrative processes and rigid organizational structures, can significantly hinder the efficiency of knowledge transfer activities.	Ahmadinejad (2020) Faborode & Ajayi (2015) Ifeanyi-obi & Asuquo (2023)
	Financial research funding and infrastructure			
	Research funding	Availability and allocation of funding		
	Lack of funding and resources for research initiatives can limit the scope and impact of knowledge transfer efforts.	Ahmadinejad (2020) Ansari et al. (2016) Bayissa (2015c) Duram & Larson (2001) Faborode & Ajayi (2015) Fongwa & Marais (2016) Helen et al. (2010) Ifeanyi-obi & Asuquo (2023) Ifeanyieze et al. (2017) Jarábková et al. (2019) Larson & Duram (2000)		
		Competitive funding	Institutions that receive competitive funding are more inclined to participate in knowledge transfer activities.	Thurner & Zaichenko (2018)
		High dependence on public funding	Institutions with a high share of their budgets coming from federal funds typically prioritize	

(*continued on next page*)

Table B.1 (*continued*)

DETERMINANTS	FACTORS	SUB-FACTORS	DESCRIPTION	EXAMPLES OF AUTHORS FROM THE SLR
			basic research over applied research, limiting their practical impact on technology transfer.	
		Short-term funding		
	Many grants offer funding for limited periods, which is inadequate for the long-term research required in agriculture.	Duram and Larson (2001)		
	Infrastructure	Infrastructure	Insufficient infrastructure and scarce resources create a barrier for academics, hindering their ability to perform effective knowledge transfer activities.	Ahmadinejad (2020) Ansari et al. (2016) Fongwa & Marais (2016) Helen et al. (2010) Ifeanyieze et al. (2017) Larson & Duram (2000) Wijerathna et al. (2015)
	Research networks			
	Research networks	Institutional networks	Lack of strong institutional linkage. Lack of coordinated networks between academic and non-academic actors restricts the flow of knowledge.	Hočevar & Istenič (2014)
Determinants related to the external environment				
Socio-cultural determinants	Adaptation to local contexts	Sensitivity to regional socio-economic and cultural conditions Alignment with local agricultural practices	The effectiveness of knowledge transfer strategies depends on adaptation to the specific cultural and socio-economic characteristics of different regions and the particular characteristics of the agricultural community.	Cruz et al. (2022) Simbe (2022)
		Cultural context	Cultural barriers, arising from differences in culture and social background, can severely hinder the transfer of knowledge to farmers from various groups or different cultural backgrounds.	Fongwa & Marais (2016)
Institutional and political determinants	Institutional determinants	Bureaucratic procedures	Impact of rigid structures and administrative complexity	Ifeanyi-obi & Asuquo (2023)
		Government investments	Role of funding in facilitating knowledge transfer	Duram & Larson (2001)
	Political determinants	Policymakers' beliefs and affiliations	The transfer of scientific agricultural research can be influenced by political beliefs and affiliations.	Getson et al. (2022)
		Nonchalant attitude of policymakers	Policymakers exhibit a disinterest or lack of enthusiasm towards incorporating research findings into practical applications.	Ifeanyi-obi and Asuquo (2023)
		Inappropriate perspectives and policy-making Inconsistent policymaking	The absence of a clear vision, along with inappropriate policies and programs, constitutes a major barrier to knowledge transfer activities. Fluctuating and inconsistent policies hinder the efficient transfer of knowledge.	Ansari et al. (2016) Bayissa (2015b) Getson et al. (2022) Helen et al. (2010) Mgbenka et al. (2013)
		Policy, funds, and administrative support		
	Lack of proper policy, adequate funds, and administrative support creates significant barriers to effective knowledge transfer.			

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